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Super-size me: Portion size effects on young children's eating

Jennifer O. Fisher *, Tanja V.E. Kral

Department of Pediatrics, Baylor College of Medicine, USDA/ARS Children's Nutrition Research Center (JOF), United States
Center for Weight and Eating Disorders, School of Medicine, University of Pennsylvania (TVEK), United States

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Abstract

Large portions of energy-dense foods are believed to favor obesity-promoting eating behaviors in young children. The following review presents evidence on food portion size effects on children's eating behavior and eating regulation, with comparison of findings to adult studies of portion size. Individual differences in children's susceptibility to portion size, particularly associations with weight status, are addressed. Finally, potential mechanisms of effects and strategies to offset the intake promoting effects of portion size are considered.

Keywords: Children; Portion size; Environment; Eating; Overweight

1. Introduction

Rapid increases in pediatric overweight in recent decades underscore the role of the environmental factors and their effects on behavior. Overweight among children has more than tripled since the early 1960s [1–3]. Current National Health and Nutrition Examination Study (NHANES) data (2003–2004) indicate that approximately 14% of children 2–5 years and 19% of children 6–11 years are overweight, a 25–35% increase since the beginning of this decade alone [3]. Among Mexican American and Non-Hispanic Black youth the prevalence of overweight ranges from 10% to as high as 27% across different age and gender subgroups. Comparison of successive NHANES surveys (1976–1994 [4] and 1971–2000 [5]) reveal upward shifts in the mean BMI as well as marked increases in body mass among overweight children. These secular changes suggest that environmental influences on body mass are acting on the population as a whole, with the most pronounced effects being shown among the heaviest children.

Obesity-promoting dietary environments are thought to favor excessive intake among children by offering convenient access to large portions of palatable, energy-dense foods [6–9]. With the first published report appearing in 2000 [10], the systematic investigation of portion size effects on young children's eating is relatively new. This review describes the small literature in this area beginning with a brief rationale for food portion size as a characteristic of obesity promoting dietary environments. Experimental research is detailed in which food portion size has been systematically manipulated to evaluate effects on children's eating. Plausible mechanisms and individual differences in children's response to portion size are in turn considered, with a focus on weight status. Finally, potential strategies to counter the intake promoting effects of large portions are considered.

2. Obesigenic dietary environments and portion size

The few available data indicate that large food portions are common in the marketplace [11,12], with the availability of large portions having increased during the same period in which the prevalence of child overweight has sharply risen [13]. Analysis of portion sizes available at fast food restaurants, chain restaurants, and independent stores revealed individual consumer portions that were often 2 to 8 times larger than USDA

* Corresponding author. USDA Children's Nutrition Research Center, 1100 Bates Street, Suite 4004, Houston TX, 70030, United States. Tel.: +1 713 798 6766; fax: +1 713 7987009.
E-mail address: jfisher@bcm.tmc.edu (J.O. Fisher).

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standards [11]. Further, current portion size offerings for selected foods and beverages (i.e., canned and fountain soda, hamburgers, french-fries, chocolate bars) were 2 to 5 times larger than the original size offered.

With the average US family spending ~40% of food expenditures away from the home [14], children's exposure to large marketplace portions is likely routine. A cross-cultural study observed that recipe portions of the same dishes from popular cookbooks were 25% larger in the US than in France [15], indicating that children's exposure to large portions likely includes foods prepared within the home. Convenience stores or fast food restaurants within walking distance of their schools [16,17] as well as a la carte options inside the schools [18] represent additional sources of exposure for the older, school-aged child. For instance, monthly aggregated sales data for 23 middle schools in Texas revealed that large bags of high-fat, high-salt snacks and 20-ounce sweetened beverages were more frequently purchased as a la carte options than smaller bags and 12-ounce sweetened beverages [18].

3. Portion size effects on children's meal and daily energy intake

Have increases in marketplace food portions affected children's consumption? There are no population level data to directly evaluate this question. However, data from the Continuing Survey of Food Intakes by Individuals revealed that the average food portion consumed per eating occasion for most foods remained relatively stable from the late 1970s to late 1990s for very young children (1–2 years) [19]. For individuals 2 years and older observed over roughly the same period, however, increases in average portions consumed were observed for numerous foods, particularly for beverages [20,21]. This was true whether focusing narrowly on 9 foods/food groups showing the greatest calorie increases in the American diet [20] or evaluating the 107 most frequently consumed foods/food types [21] during the time period of interest. One of the analyses showed significant increases in average portion consumed per eating occasion for 23 of the 107 most frequently consumed foods/food types in the American diet between 1989–1996 [21], with 11 of those involving beverages.

4. Portion size effects on children's meal and daily energy intake

To date, there have been three cross-sectional and five experimental investigations of portion size effects on children's food and energy intake.

4.1. Survey research

Three nationally-representative cross-sectional studies have reported positive associations of average food portion sizes consumed and daily energy intake in children ranging from 6 months to 5 years of age [19,22,23]. For instance, data from the Continuing Survey of Food Intakes by Individuals (1994–1996, 1998) were used to determine average portion sizes for the top 10 most frequently consumed foods in the diets of 2- to 5-year-old children [23]. Portion size accounted for 17–19% of the variability in energy intakes—similar to the proportion of variance explained by the number of eating occasions, number of foods in the diet, and body weight combined. Collectively these findings establish an association between food portion size and children's energy intake at the population level. The ability to infer cause and effect from the observational data is limited by the fact that energy intake necessarily reflects the amount (i.e., portion size) and energy density (ED; kcal/g) of food that is consumed as well as how frequently eating occurs. Moreover, the size of the amount consumed cannot directly address the correspondence between the amount of food available and food intake.

An exception is a small study evaluating the relationship between serving size and consumption over a 5–7 day period in 16 4- to 6-year-old children [24]. Serving size and children's intake were assessed by weighed food records while they were in preschool and by parents' estimates using conventional household measures at home. A strong positive correlation ($r=0.77$, $p<0.001$) was observed between the weight of food served and that consumed at individual meals. The cross-sectional nature of this and the aforementioned studies, however, limits inferences regarding causality. For instance, children's requests may have influenced the amount served at meals.

4.2. Single meal studies

In the first experimental study, a macaroni and cheese entrée was served in small, medium, and large portions (tailored to child) age, to 32 2- to 5-year-old children at three separate lunches along with fixed portions of other foods [10]. Among 4- to 5-year-old children, intake in the large portion condition was 60% greater than in the small portion condition (77 g vs. 123 g). An effect of portion size on intake was not observed in a younger group of 2- to 3-year-old children. The findings suggested a developmental shift in children's susceptibility to portion size. The basis of the development differences in children's response as well as the reproducibility of the effects, however, was unclear.

A second study involving 3- to 6-year-old children was designed to further explore age-related differences in children's intake of large portions, served on repeated occasions [25]. Children's ($n=31$) entrée and total meal energy was measured at series of 4 lunches in each of two conditions: one in which a macaroni entrée was of a reference amount and a second condition in which the size of the entrée was doubled. Children's comments about portion size, eating microstructure variable (i.e. bite frequency, bite size), and children's self-served portion sizes were assessed to further characterize potential age-related changes in children's susceptibility to large portions. Doubling the entrée portion resulted in a 25% increase in the intake of the entrée and a 15% increase in total energy consumed at the lunch. The effects were observed the first time the large entrée was served and did not vary with time, indicating that effects were immediate and sustained with repeated exposure. That children consumed, on average, only 67% of the age appropriate entrée size suggested

that doubling the serving size caused consumption in excess of that normally consumed. Counter to expectations, however, age was unassociated with the effects of portion size on children's entrée consumption. Older children, however, did show larger increases in total meal energy across conditions than the younger children.

While the aforementioned studies tailored entrée serving size to children's age, the difference in age between younger and older groups of pre-school-aged children was only a year or less. The third experimental investigation used more distinct age groups to specifically evaluate age-related effects in children's response to portion size [26]. Seventy-five non-Hispanic white children in three age groups (2–3 years, 5–6 years, and 8–9 years) were seen at a dinner meal in which a macaroni entrée was either of a reference size or doubled. Effects of age on children's intake of the large portion were not significant. Entrée consumption was 29% greater and meal energy intake was 13% greater in the large portion condition than in the reference condition (Fig. 1). These data demonstrated that children as young as 2 years of age were affected by portion size, suggesting that developmental changes in susceptibility are likely of a magnitude smaller than previously suspected.

4.3. Effects on daily intake

To date, there has been only one study to evaluate effects beyond a single meal. A within-subjects experimental design with reference and large portion size conditions was used with 59 low-income Hispanic and African American preschool-aged children and their mothers [27]. The portion size of 3 entrées (lunch, dinner, and breakfast) and an afternoon snack served during a 24-hour period were of a reference size in one condition and doubled in the other. Doubling the portion size of several entrées and a snack served during a 24-hour period increased energy intake from those foods by 22% (~180 kcal). Significant increases in intake, however, were only observed for 2 of the 5 individual foods for which portion size was manipulated (chicken nuggets and cereal entrées), but not for macaroni and cheese as observed in the previous studies. Compensatory reductions in the intake of other foods were not observed. Consequently, total energy intake in the large portion condition was 12% greater ($p<0.001$) than in the reference condition. These findings demonstrate portion size effects on intake beyond a single meal in two understudied ethnic groups who are disproportionately affected by overweight [3]. Further, effects on energy intake were produced by a relatively modest manipulation involving approximately one-quarter of all foods and beverages served. At the same time, the data revealed inconsistencies in portion size effects by food type, the basis of which remains unclear.

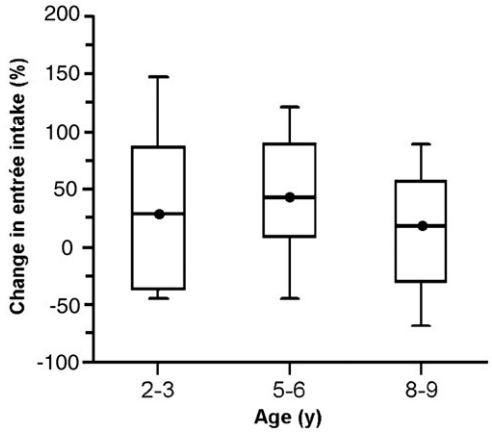

Fig. 1. Intake of entrée in large portion condition relative to reference condition. Percent change in children's gram consumption when a reference entrée portion was doubled. Children's entrée consumption in the large portion condition was 29% greater than in the reference condition ($F=11.0$, $p<0.001$). Means (±SEM) for 2–3 years, 5–6 years, and 8–9 years groups were 29±21%, 43±14%, and 18±13%, respectively; however, differences were not statistically significant. The sample mean is given by the horizontal line. Lower and upper edges of the box represent the 25th and 75th percentiles, respectively. Lower and upper boundaries of the whiskers indicate the 10th and 90th percentiles, respectively. Reproduced with permission from *Obesity*.

4.4. Interaction with food ED

Whether children compensate for increased intake from large food portions is of interest because experimental and observational studies suggest that young children possess the ability to self-regulate energy intake. For instance, pre-school-aged children have demonstrated the ability to self-regulate energy intake at meals [28,29] and over the course of 30-hour periods [30–32]. Children accurately adjusted ad libitum intake at a meal in response to covert manipulations made to the ED of foods consumed within the hour prior to the meal [28,29,31]. Alternatively, observational research indicates that children show less sensitivity to ED under free-living conditions. A study of 1675 1- to 4-year-old children revealed increases in total daily energy intake across three levels of increasing dietary ED [33]. Similarly, when the ED of an entrée was experimentally reduced by 30%, 2- to 5-year-olds consumed 25% fewer calories [34]. An effect of increasing ED to promote energy intake has been reported in observational and experimental investigations of adults [35–38].

Given the seemingly conflicting findings on ED and children's self-regulation, an experimental approach was taken to understand the extent to which food ED influences children's response to portion size [39]. Participants were 53 (28 female and 25 male; 15 Hispanic, 20 Black, 16 white, 2 other) 5- to 6-year-old children. A 2×2 within-subjects design was used to manipulate entrée portion size (250 g vs. 500 g) and ED (1.3 kcal/g vs.1.8 kcal/g). Based on a design used to study ED in adults, the ED of the main dinner entrée varied by 40% across conditions via manipulations in fat (oil) and water content [40]. Fixed portions of other familiar foods were provided. Effects of portion size and ED on entrée energy intake were independent, but additive. Energy intake from other foods at the meal did not vary across conditions. Compared to the reference portion size and ED condition, children consumed 76% more energy from the entrée and 34% more energy at the meal when served the larger, more energy-dense entrée (Fig. 2).

A second study similarly decreased entrée ED (1.6 kcal/g vs. 1.2 kcal/g) and portion size (400 g vs. 300 g) by 25% across conditions and tested effects on 3- to 5-year-old children's lunch

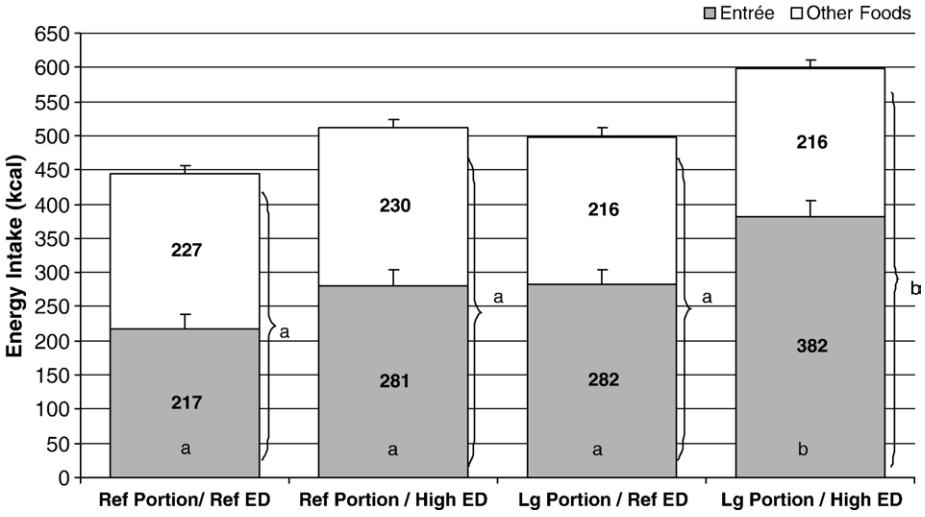

Fig. 2. Effects of portion size and energy density on energy intake. ED = energy density, Ref = reference, Lg = large. ANOVA was used to test effects of portion size and ED on energy intake (kcal), adjusted for child age, sex, ethnicity, child BMI *z*-score, entrée preference, and eating ≥95% of the reference portions ($n=53$). Data are presented as LS means (±SEM); different letters signify mean differences, $p<0.01$. Main effects of portion size on entrée energy intake ($F=19.87$, $p<0.0001$) and total meal energy ($F=13.34$, $p<0.001$) were observed. Main effects of ED on entrée energy intake ($F=19.79$, $p<0.0001$) and total meal energy ($F=19.07$, $p<0.0001$) were observed. Neither portion size ($F=1.55$, $p=0.21$) nor ED ($F=0.01$, $p=0.92$) affected energy intake of other foods. Portion size effects on energy intake did not interact with ED. Reproduced with permission from *The American Journal of Clinical Nutrition* (will be obtained).

intake [41]. Results showed that ED, but not the portion size of the entrée, significantly affected children's energy intake. The lack of an effect of portion size is surprising given the results of previous studies [10,25–27,39]. It is possible that differences in the magnitude of the portion size manipulation may have affected children's response. Alternatively, the ED findings were consistent across studies, suggesting that controls of meal size are relatively insensitive to covert changes in food ED. Why increases in entrée ED increased meal energy (i.e., reduced satiation) in these studies but decreased energy intake during a subsequent meal when ingested as a preload (i.e., increased satiety) in others [28,29,42] is unclear. Additional research is needed to understand the basis of apparent differences in effects of food ED on young children's satiation and satiety.

In summary, the observational and experimental findings are generally consistent, supporting an intake promoting effect of large portions on children's meal and daily energy intake. The fact that the single meal studies all used a single type of food limits generalizations to foods of varying form (solid vs. liquid), shape (amorphous vs. unit), and taste preference but facilitates comparisons across studies. Children's entrée consumption increased across studies [10,25–27,39] by approximately 1/4 [27] to 1/3 [39] when entrée portion size was doubled, although the initial study reported an increase of almost 2/3 among 5-year-olds [10]. Among those studies reporting portion size effects [10,25–27,39], energy intake from other foods served at the test meals was remarkably invariant across conditions. That a compensatory decrease in intake of the other foods was not observed suggests a capacity of portion size to alter children's satiation (i.e., meal termination). As a result, meal energy intake increased across studies [10,25–27,39] by 13% [26] to 39% [10] and daily energy intake by 12% [27] when portion sizes were doubled.

The failure to observe effects in the study using a more conservative manipulation (entrée portion increased by 33% across conditions) [41] of entrée portion size underscores the subjective nature of experimental definition of 'large' portion sizes. The findings indicate the need for research aimed at understanding the point at which portion sizes become 'large' enough to exert significant effects on eating.

5. Do children and adults respond similarly to large food portions?

Portion size effects on adult intake have been demonstrated at single meals in laboratory [43–50] and naturalistic settings [51], for unit [43,49,52] and amorphous foods [44], beverages [50], foods of varying ED [47,48], pre-packaged snacks [46] and first course salads [45]. Two adult studies have reported sustained effects on energy intake over 2- [53] and 11-day [54] periods. A number of the child and adult studies have used parallel research questions, designs, and methodology, thereby facilitating comparisons of portion size effects on intake between groups.

5.1. Amorphous entrée foods

Food shape is a potentially important dimension of portion size research because children [55] and adults [56] have greater difficulties judging the size of amorphous foods than of more distinctly shaped foods (i.e. sandwich). Like all of the experimental studies in children, two of the single meal studies in adults have utilized an amorphous pasta entrée to evaluate portion size effects. Ad libitum meal intake of 51 adult men and women was assessed in a laboratory setting on 4 separate occasions during which a macaroni and cheese entrée was served in different portion sizes (500, 625, 750, or 1000 g) [44]. Adults ate 30% more energy (161 kcal) when served the largest entrée than when served the portion half its size.

A study conducted in a cafeteria-style restaurant increased the portion size of a pasta entrée, served on two separate days, by 50% (248 g vs. 377 g), without any change to price [51]. Though ratings of perceived size did not vary between the two portions offered, entrée intake was increased by 43% (172 kcal) and meal energy by 25% (159 kcal) when the larger entrée was offered than when the smaller portion was served. Consistent with the child data, the findings provide evidence of increased adult energy intake at a single meal with increases to the portion size of an amorphous entrée.

5.2. Interactions with ED

Using manipulations almost identical to the child study, a main entrée at lunch was formulated in 2 versions that varied in ED (1.25 or 1.75 kcal/g) by 40% each of which was served in 3 different portion sizes (500, 700, or 900 g) ([47] Kral, Roe, Rolls). Energy intake was affected by both the portion size and the ED of the entrée. That is women consumed 56% more energy when served the largest portion of the more energy-dense entrée than when served the smallest portion of the lower energy-dense entrée. Thus, the adult findings are in agreement with one child study in which portion size and ED appeared to exert independent but additive effects on intake at a lunch meal [39].

5.3. Long-term effects

Adult studies have demonstrated increases in energy intake over 2 days [53] or 11 days [54] when all food and beverage portions were increased. One study of 32 adult men and women observed a 16% (335 kcal) increase in daily energy when all food and beverage portions were increased by 50% during a 2-day period [53]. A second demonstrated that a 100% increase in portion size resulted in a 26% increase in total energy consumed over an 11-day period [54]. The only study in children to evaluate effects beyond a single meal demonstrated a comparable 12% increase in total energy intake when the portion size of several entrées and a snack served during a 24-hour period was doubled [27]. The mothers of those children showed a 9% increase in total energy intake when using a similar portion size manipulation. These findings point to similar sustained increases in energy intake in adults and children when the portion size of foods is increased over a prolonged period of time.

In summary, a comparison of findings from portion studies conducted with adults and children indicates similarities in effects on meal and daily energy intake. Combining ED and portion size showed additive effects on intake in adults and 5- to 6-year-old children, while another study conducted with 3- to 5-year-old children only showed an effect of ED, but not portion size on intake.

6. Potential mechanisms: the role of visual cues and bite size

The mechanisms of portion size effects on children's eating are not well elucidated. Some have argued that the effects of large portions on eating can be explained in terms of inflated perceptions of 'normative' or 'appropriate' intake [57–59] that are conveyed by visual cues associated with large food portions.

6.1. Cognitive explanations

Several studies observed that adults were often aware of increases to the portion size of foods and beverages made in a laboratory setting. Subjects rated food portions as being increasingly larger than their usual portions across conditions in which the serving amount increased [47,49,50,53]. This was true when evaluating portion size perceptions of an amorphous entrée [47], a unit food (i.e., sandwich) [49], beverages [50] and, more recently, all foods consumed over the course of 2 days [53]. The fact that intake increased in conjunction with adults' perception of increasing portion size does not provide direct evidence of mechanism, but is certainly consistent with the notion that large portions 'sanction' greater intake [47,49,50,53].

Limited evidence suggests that portion size effects on children's eating are not explained by 'consumption norms'. Behavioral observations made in two of the studies revealed that children were relatively unaware of the increases to entrée portion size [25,26]. In one of the studies, only 7 of 75 children commented on the size of the large portion (i.e., "This is a lot of mac and cheese"); one child made similar comments in the reference portion condition [26]. Further, the notion that the findings reflected a motivation to 'clean the plate' seems unlikely given that the children tended not to consume the smaller portions in full; the proportion of the reference portions consumed across studies was (in ascending order) 32% [10], 56% [26], 63% [27], 67% [25], and 84% [39].

6.2. Visual cues

Subtle visual cues pertaining to the portion size of foods are also thought to contribute to intake effects in children. Volume illusions [60] have been shown to alter portion perception, selection, and consumption of liquids among adolescents [61] and adults [62]. Adolescents served themselves and consumed approximately 75% more juice when using a short (10.6 cm), wide glass than a taller (18.9 cm), narrower glass of the same volume capacity (22.3 oz) [61]. Effects of eating container size may also extend to bowls and plates. For both children and adults, the context in which an object of a given area is presented can affect judgment of its size [63]. Food vessel size might be an important modifier of portion size effects in that studies of visual illusions have demonstrated that children and adults perceive circles of a given size as being larger when surrounded by smaller sized circles than when displayed with larger circles [64]. Two adult studies provide evidence that the amount of self-served portions is influenced by food vessel size. The average size of each spoonful taken from a serving dish was shown to increase as the amount of the entrée in the dish increased; the mean amount per spoonful was 49±3, 52±3, 64±7, and 55±3 g in the 500-, 625-, 750-, and 1000-gram entrée serving size conditions [44]. In another study, adults given a 34-ounce bowl served themselves 31.0% more ice cream (6.25 vs. 4.77 oz,

$p<0.01$) than adults using a 17-ounce bowl, with little difference in awareness of the amount served [65]. However, a recent study involving three cross-over experiments found no evidence of effects on intake, when plate size was systematically varied [66]. Whether these findings were produced by visual cues alone or also involved cognitive explanations such as consumption norms or monitoring accuracy was not possible to discern.

The visual cues to which children attend when making judgments about food portion size are not well understood. Prior to age 8, children tend to focus on one aspect of an object's size (e.g., height) and lack conservation of mass/volume [67]. A recent study used a within-subject design to test the effects of portion size (reference—275 g vs. large—550 g), plate size (6″ vs. 10″), and food diameter (4″ vs. 8″) on 5- to 6-year-old children's perceptions of entrée portion size. Five presentations, varying in macaroni and cheese portion size, plate size, and food diameter were used. Children were shown each possible pair (5 presentations; 10 pairs) and asked to indicate whether the entrée amounts differed, and if so, to indicate the one with the larger portion. Most (88%) children correctly identified the larger portion when it had twice the diameter of the smaller portion and was served on a larger plate (10″). In fact, most children perceived the portion size to be larger when the diameter of equal portions (275 g) was doubled (4″ vs. 8″), whether plate size was held constant (44/52 children) or not (46/52 children). Alternatively, only 27% of children perceived a portion size difference when the smaller portion was spread out to have the same diameter (8″) as the larger portion and was served on the same size plate (10″).

6.3. Bite size

Behavioral observations of children's response to portion size support the hypothesis that visual cues associated with portion size alter the microstructure of eating. For instance, two studies observed that serving large entrée portions increased children's average bite size while having no effect on bite frequency [4,26]. Fisher et al. observed a 25% increase in children's consumption when the portion size of a lunch entrée was doubled [25]. This increase was primarily attributable to increases in the average size of children's bites, without change in the total number of bites taken. Further, observational data revealed that few children were aware of changes to the size of the entrée portion. A second study of 2- to 9-year-old children produced similar results. The portion size of a macaroni and cheese entrée served at a dinner meal was of a reference amount (200 g for children 2–3 years, 250 g for children 5–6 years, and 450 g for children 8–9 years) on one occasion and doubled on another. When average entrée bite size was assessed across the full range of entrée serving sizes used (200–900 g) a positive association was observed. Interestingly, increases in bite size were apparent even among children who did not eat more when the entrée portion was doubled; those children took larger bites, but fewer total bites of the entrée when served the large portion than the reference portion (Fig. 3). Taken together, these findings indicate that large portions produce general increases in children's average bite size, but do not have uniform effects on bite frequency. Why some children took a greater number of larger bites than other children is unclear. Further, the eating rate and duration were not evaluated.

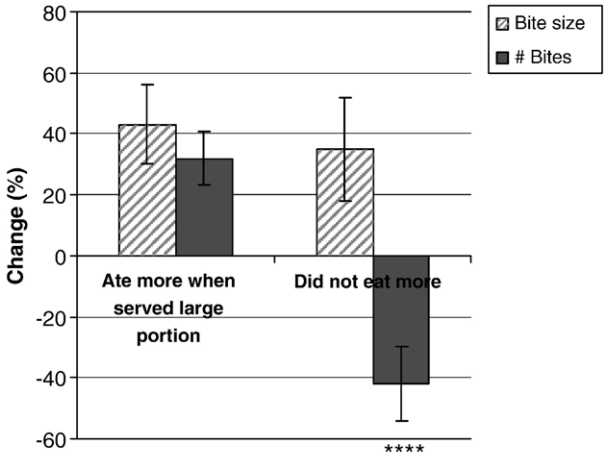

Fig. 3. Changes in bite number and size among children who ate more of the entrée in the large portion condition than in the reference condition and for children who did not. Data are presented as mean ± SEM. Children who ate more of the large portion entrée showed increases in both bite size ($p<0.01$) and the total number of bites taken ($p<0.001$). In contrast, children who ate the same amount or less of the large portion showed increases in bite size when served the large portion ($p<0.05$) but decreases in the total number of bites taken ($p<0.001$). ****$p<0.0001$; different than value observed among children who ate more when served the large portion. Reproduced with permission from *Obesity* (will be obtained).

In summary, in contrast to adults, children seem largely unaware of changes in the portion size of amorphous foods when doubled in a laboratory setting. Children's perception of portion size appears to be influenced by food diameter and height. Visual cues related to portion size appear to alter the microstructure of eating, specifically bite size, although the specific visual cues that produce these changes are not understood. Further, whether aspects of eating microstructure beyond bite size, such as eating rate and duration are affected by portion size remains to be evaluated. Additional research is needed to evaluate the extent to which cognitive perceptual factors relating to food portion size exert their effects on children's eating.

7. Role of weight status and individual differences in children's response to portion size

Characterizing portion size effects on children's eating is ultimately directed to evaluating its role in the development of overweight. The fact that already overweight children have become markedly heavier in recent decades [4,5] suggests that environmental factors, like portion size, have not had uniform effects across the distribution of child weight or body mass. Indeed, cross-sectional investigations reveal positive associations of weight status with average food and meal portion size among toddlers and adolescents participating in the Continuing Survey of Food Intake by Individuals, 1994–1996, 1998, but not among pre-school-aged children [19,68]. To date, however, none of the experimental studies have established a relationship between portion size effects and either child BMI [10,25–27,39] or

familial 'risk' as indicated by maternal BMI [26,27,39], maternal disinhibition [26], or maternal intake of large portions [27]. The failure to associate portion size effects with weight status is consistent with most [44–50] but not all [43] of the laboratory-based adult studies. Taken together, the evidence suggests that the tendency to overeat large portions is not specific to overweight children (and adults). Following, the implications of portion size for child overweight may be principally informed by the extent to which children are routinely exposed to large portions. Prospective studies are needed to evaluate the effects of sustained exposure to large food portions on children's weight gain trajectories and to examine how socio-economic, cultural, and family factors may influence children's routine exposure to large portions.

Like child weight status, the experimental studies have largely failed to associate basic subject characteristics (i.e. sex [10,25–27,39], ethnicity [27,39]) with the considerable variability observed in children's intake of large portions in the laboratory. For instance, doubling the portion of an entrée resulted in increases in food intake ranging from a 44% decrease to a 109% increase in entrée intake, with a mean increase of 25% [25]. Similarly, effects of portion size on daily energy intake in the study of 59 Hispanic and African American preschoolers ranged from a 31% decrease to a 96% increase in energy intake across reference and large portion conditions, with a mean increase of 12% [27]. It is unclear whether the measurements are not sensitive enough to meaningfully characterize variation or whether there are psychosocial, perceptual, or biological explanations yet uncharacterized. One of the first experimental studies in children [4] observed portion size effects on total meal energy intake to be positively correlated ($r=0.41$) with a separate laboratory measure of eating in the absence of hunger, suggesting an association between satiation and satiety deficits (i.e., inter-meal interval). The findings of a recent population-based study of 17,357 European women suggest that genetic variation in hormonal regulators of appetite might explain the variability in effects [69]. Obese carriers of common allelic variations in cholecystokinin (CCK) had increased risk of eating excessive portion sizes. Additional research is needed to determine the reproducibility and sensitivity of portion size estimates as well as to understand why some children may be more likely to overconsume large portions than others.

8. Strategies to counter portion size effects

Findings of portion size effects on energy intake underscore the need for evidence-based strategies which may be applied by parents to attenuate increased intakes in their children when living in obesity-promoting environments. An unexpected finding of one of the first experimental studies suggests that allowing children to serve themselves may negate the intake promoting effects of large portions.

In one study, children's self-selected portions were evaluated at 4 lunches [25]. When allowed to serve themselves from a bowl containing a large portion of the entrée, children selected an amount of the entree similar to the smaller, reference-sized portion. Further, children consumed 24±8% more when served the large portion than when serving themselves. A strong positive correlation ($r=0.76$, $p<0.001$) was observed between children's self-determined entrée portion sizes and their entrée intakes. These findings were only partially replicated, however, in a second study of 2- to 9-year-olds in which intake of reference, large, and self-served entrée portions was assessed at a dinner meal [25]. Intake in the self-served condition did not differ from intake in the large portion condition for the sample as a whole. However, among those children who tended to 'overconsume' the large entrée relative to the reference portion, self-serving appeared to be beneficial. Those children consumed 17% less of the entrée and 11% less total energy at the meal when allowed to self-serve than when the large portion was served to them.

In contrast to the findings in children, the method by which a pasta entrée was served to adults did not significantly affect their intake. In a between-subjects design Rolls et al. [44] investigated whether the response to portion size depended on which person, the subject or the experimenter, determined the amount of food on the plate. Men and women were presented with a pasta entrée, consumed for lunch, which differed in portion size (500, 625, 750, or 1000 g) across conditions. One group received the pasta on a plate; participants in the other group self-determined the portion on their plate by serving themselves from a serving dish. Results showed no interaction between serving method and portion size indicating that portion size affected intake similarly, whether subjects served themselves or whether someone else determined the portion on the plate. Thus, the intake-reducing effect of self-serving appears to only apply to children and not to adults.

It is possible that the lack of an intake-reducing effect of self-serving in adults may be due to a distorted perception of what constitutes 'appropriate' serving sizes for foods and beverages. Two recent studies indicated that adolescents and young adults self-determined portions were not often in line with recommended serving sizes. A study of 177 young adults between the ages of 16 and 26 years, evaluated self-served portions of commonly consumed foods compared to recommended or reference values [70]. Participants' self-generated 'typical' portion sizes of eight foods and beverages normally consumed at breakfast ($n=63$) and six foods and beverages normally consumed at lunch or dinner ($n=62$, $n=52$, respectively) were unobtrusively weighed. The results revealed that only 45% and 32% of the portion sizes selected by participants at breakfast and lunch/dinner, respectively, were within 25% more or less than the recommended portion size. In addition, typical portion sizes for several of the food and beverage items (e.g., cornflakes, milk on cereal, orange juice) were significantly larger than those reported in a similar study [71] which was conducted 2 decades ago.

In another experiment [72] of 51 college-age adults, self-served 'typical' portions of 15 foods and beverages which varied in their caloric content and form (i.e., amorphous solid, amorphous semisolid, and liquid) were assessed. Results revealed that subjects chose portion sizes that were significantly larger than the recommended amounts for approximately two thirds (10 of the 15) of the food and beverage items. The data also showed that participants' BMI was a strong predictor of selecting larger than recommended portions of foods/beverages, accounting for 28% to 51% of the variance in participants' choice.

In summary, preliminary evidence indicates that allowing children to self-determine portion size may counter the intake promoting effects of large portions. Identifying influences on children's self-served portion size is needed to explain why the strategy may be helpful for some, but not all children. Studies of children's perception of normative or appropriate portions, in particular, may be helpful for understanding how children arrive at customary or typical self-served portion sizes. The failure to demonstrate benefits of self-serving in adults in conjunction with often larger than typical self-determined portion sizes raises the possibility of developmental changes in the behavioral controls of eating. It is possible that adults adjust their portion size norms (and self-served portions) over time as a result of being repeatedly exposed to large portions of foods and beverages in their environment.

9. Summary and conclusions

In summary, findings from the cross-sectional studies and most, but not all of the experimental research, indicate that large portions of energy-dense foods foster obesity-promoting eating behaviors by increasing energy intake among children as young as 2 years of age. Overall, the portion size effects on intake that are seen in pediatric populations seem to parallel those seen in adults. However, data also suggest that developmental factors may be implicated in children's response to portion size. In particular, some children appear to eat less when allowed to self-determine portion size than when presented with large portions, however, intake in adults seemed to be unaffected by serving method. Comparison of adult and child studies using similar designs and methodology may be an important strategy to further elucidate these factors that affect children's response to portion size.

Mechanisms by which portion size exerts its effects on intake in both children and adults are yet poorly understood. Visual cues are believed to play an important role not only in individuals' ability to correctly discern differences in portion size, but they also are thought to act as possible modifiers of eating behavior (e.g., bite size) within a meal. More studies are needed which further examine the impact of visual and cognitive aspects of portion size perception on eating behavior and intake regulation in both children and adults. Additional research is also needed to develop strategies to prevent excess energy intake in children.

In conclusion, growing evidence suggests that large food portions foster obesity-promoting eating behaviors in children by increasing mealtime and daily energy intake. Efforts to further elucidate the mechanisms by which portion size exerts these strong effects on intake and possibly on children's weight and weight development will be crucial for the prevention and the treatment of childhood obesity.

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