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CHILDREN'S BEHAVIORAL RESPONSES TO PORTION SIZE

A Thesis in

Nutrition

by

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ABSTRACT

Background: Childhood obesity has increased dramatically in recent decades; currently more than 30% of children are overweight or obese. The portion sizes of many commonly consumed foods have also increased substantially during this period and large portions may be contributing to the obesity epidemic. Previous research has shown that doubling the portion size of an entrée can significantly increase children's intake at a meal. However little is known about how increasing entrée portion size, from small to very large affects children's intake and eating behavior.

Objectives: 1) To test a) how increasing portion size increased entrée intake, number of entrée bites, time spent eating the entrée or estimated bite size, b) whether these relations differed by child's weight status and c) whether number of entrée bites, or time spent eating the entrée predicted children's entrée intake; 2) to investigate changes in eating rate from the beginning to the end of a lunch session and whether changes in eating rate were related to children's weight status; and 3) to test a) whether self-served entrée size was related to children's weight status, and whether there was any difference between 400g condition and self-served condition with regards to entrée consumption and b) whether children's estimated bite size or number of bites differed by weight status during this condition.

Methods: Participants were 17 3 to 5-year-old children. A within-subject design was used to evaluate food consumption during a series of six lunches, in which 100, 160, 220, 280, 340 and 400 g entrées were served in one random order. Each child's eating behavior was recorded by two cameras during the lunch. Two trained coders recorded the number of entrée bites taken by each child; inter-rater reliability was .99. Estimated bite size of an entrée was defined as total grams of entrée consumed divided by total number of bites taken. Time spent eating the entrée was calculated by subtracting the time at the last bite of the entrée from the time at the first bite. To calculate eating rate, the data from 340g portion lunch was used and changes in eating rate during the entire 20 minutes of lunch time were investigated across four five-minute intervals. Children's food consumption and eating behavior was assessed during one lunch of self-served condition. Age and sex-specific BMI percentiles were calculated.

Results: As portion size increased from 100 to 400 g, a significant interaction was found between BMI percentiles and portion size to predict entrée consumption. Children with higher BMI percentiles showed greater increases in entrée consumption with increasing portion size. Given the low variability in g intake of the entrée among participants within the two smallest portions, the analyses were also conducted excluding the 100g and 160g portions. The interaction of portion size and BMI percentiles was no longer significant. However, BMI percentiles and portion size were significant predictors of entrée intake. A significant interaction was found between BMI percentiles and portion size on number of entrée bites, such that children with higher BMI percentiles had greater increases in the number of entrée bites when portion size increased. No significant interactions were found between BMI percentiles and portion size to predict time spent eating the entrée or estimated bite size. There was a significant main effect of portion size on time spent eating the entrée and bite size. Number of entrée bites and time spent eating the entrée were significant predictors of entrée intake. Eating rate decreased from the beginning to

the end of the meal and the changes in eating rate were moderated by BMI percentiles, with overweight children failing to show significant decreases in eating rate. In self-served condition, overweight children showed greater entrée intake and greater number of entrée bites than non-overweight children. The grams of the entrée that were self-served and the proportions of food eaten to food served did not differ between overweight and normal weight children. No significant differences in intake were found between self-served and 400g portion condition.

Discussion: Increasing portion size across a wide range of portions increased children's entrée intake by increasing number of entrée bites, and time spent eating the entrée. A moderating effect of weight status was noted for entrée intake and number of bites, suggesting that children with higher BMI percentiles are more responsive to the larger portions by eating more and taking greater number of entrée bites. Number of entrée bites, and time spent eating the entrée predicted children's entrée intake, illustrating how these increased behavioral responses to the increased portion size may lead to greater entrée intake. Unlike normal weight children whose eating rate slowed as the meal progressed, overweight children's eating rate did not slow significantly during the course of the meal, suggesting that deficient satiation may have been responsible for greater intake of overweight children. Findings from self-served condition were similar to those from portion size manipulation in which overweight children showed greater intake and number of entrée bites. These findings are not consistent with those of previous studies, which have shown that allowing children to self-serve portions mitigates effects of large portions. This research suggests that increasing portion size may increase children's intake via changes in number of entrée bites and time spent eating the entrée and also suggests the possibility that children with higher BMI percentiles may be more responsive to large portions.

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Chapter 1

Introduction

Increasing prevalence of obesity and portion size

Over the past few decades, obesity and overweight have become epidemic in United States. The 2007-2008 National Health and Nutrition Examination Survey showed that among children and adolescents aged 2 through 19 years, 11.9% were at or above the 97th percentile for age- and sex-specific BMI; 16.9% were at or above the 95th percentile; and 31.7% were at or above the 85th percentile (Ogden, Carroll, Curtin, Lamb, & Flegal, 2010). The increased prevalence of childhood obesity includes all ethnicities (Freedman, Khan, Serdula, Ogden, & Dietz, 2006; Mei et al., 1998).

Childhood obesity is related to the risk of many acute and chronic diseases as well as psychological problems. The physical health of obese children is affected by orthopedic complications, gastroenterological problems, and many endocrine/ metabolic abnormalities (Must & Strauss, 1999; Wills, 2004). Obesity also contributes to the development of metabolic syndrome and diabetes among children (Aye & Levitsky, 2003; Cruz & Goran, 2004). Based on current trends, diabetes will occur in one in three children (30% of boys and 40% of girls) born in 2000 (Institute of Medicine, 2004; McConnaughey, 2003). Type 2 diabetes mellitus has accounted for 8% to 45% of new pediatric cases of diabetes reported in the 1990s, compared with less than 4% before 1990 (Institute of Medicine, 2004). In fact, obesity increases lifetime risk of type 2 diabetes mellitus, so that increases in obesity prevalence could reverse historical trends of increased life expectancy. In addition, although higher weight status in childhood is a strong predictor of being obese in adulthood (Field, Cook, & Gillman, 2005; Freedman, Khan, Dietz, Srinivasan, & Berenson, 2001; Guo, Roche, Chumlea, Gardner, & Siervogel, 1994), childhood obesity predicts adult morbidity, independent of adult weight status (Dietz, 1998; Freedman et al., 2008).

Obese children are also more likely to have low self-esteem (Strauss, 2000). Strauss found that females who were obese during childhood had lower levels of self-esteem by early adolescence, which was associated with sadness, loneliness, and nervousness and higher risk of engaging in smoking or consuming alcohol. In turn, lower self-esteem during childhood has been shown to be a strong predictor of weight gain into adulthood (Ternouth, Collier, & Maughan, 2009). The adverse outcomes associated with childhood obesity are not limited to health outcomes. In the past three decades, the annual economic cost of obesity-related diseases for children and adolescents increased 6.8 times, from $35 million in 1979-1981 to $237.6 million in 2001-2005 (Trasande, Liu, Fryer, & Weitzman, 2009; Wang & Dietz, 2002).

Dramatic and rapid increases in childhood obesity prevalence cannot be explained solely by genetic factors, suggesting that obesity is expressed when genetically susceptible individuals are placed in obesogenic environment (French, Story, & Jeffery, 2001; Hill, 2006; Hill & Peters, 1998; Hill, Wyatt, Reed, & Peters, 2003; Popkin, Duffey, & Gordon-Larsen, 2005; Poston & Foreyt, 1999). The distribution of children’s body mass index has changed rapidly over time, supporting hypotheses of environmental effects at the population level; findings from national survey data have shown ascending shifts in mean BMI as well as significant increases in body mass among children in the upper part of the distribution (Flegal & Troiano, 2000; Jolliffe, 2004; Ogden et al., 2006; Ogden, Carroll, & Flegal, 2008). Obesity results from positive energy balance, where energy intake is chronically higher than energy expenditure. Rapid changes in environments have occurred in a direction that promotes this positive energy balance by offering easy access to large portions of energy dense, inexpensive, palatable foods and a sedentary lifestyle (French et al., 2001; Hill & Peters, 1998; Hill et al., 2003; Poston & Foreyt, 1999). Although while acknowledging importance of physical activity, food energy density, snacking, frequent eating and the other factors that are related to intake and weight gain, the focus of this research is on one factor: the effect of increasing portion size on children's patterns of food consumption, and whether these effects are moderated by children's weight status.

Childhood obesity has increased during a time period, in which the portion sizes of many foods have also increased dramatically, especially for the foods consumed outside the home (Nielsen & Popkin, 2003; Young & Nestle, 2002, 2007). Market place portions have exceeded the USDA standard serving sizes notably by two to eight times (Young & Nestle, 2003). In addition, Young and Nestle reported that portion sizes of fast foods are two to five times larger than the original sizes introduced a few decades earlier. Because 49% of food expenditure happens away from home (United States Department of Agriculture, 2008), children's exposure to large portions of energy dense foods is unavoidable.

Because portion sizes of frequently consumed foods have grown in parallel with increases in obesity prevalence, there may be some causal connections between these two events. Cross-sectional epidemiological studies have shown positive relations between weight status and portion size among toddlers and adolescents participating in the Continuing Survey of Food Intake by Individuals (CSFII), 1994-1996, 1998, but not among children in pre-school age (Huang, Howarth, Lin, Roberts, & McCrory, 2004; McConahy, Smiciklas-Wright, Birch, Mitchell, & Picciano, 2002). In previous experimental studies, children's response to portion size has not been related to child weight status (Fisher, 2007; Fisher, Arreola, Birch, & Rolls, 2007; Fisher, Liu, Birch, & Rolls, 2007; Fisher, Rolls, & Birch, 2003; Rolls, Engell, & Birch, 2000). However, the lack of relations between children's response to portion size and their weight status may be because many of these studies were not designed to address this question or may be they included a limited number or range of portion sizes, or because overeating as a consequence of large portions occurs among all children, regardless of weight status.

Relations between portion size and food intake

To investigate short-term influences of portion size, researchers have investigated relations between food portion size and energy intake. Cross-sectional studies have revealed positive relations between average portion size consumption and daily energy intake among children 6 months to 5 years old (Fox, Devaney, Reidy, Razafindrakoto, & Ziegler, 2006; McConahy et al., 2002; McConahy, Smiciklas-Wright, Mitchell, & Picciano, 2004). For example, data from CSFII in 1994–1996 and 1998 showed that portion size accounted for 17-19% of the variability in energy intake (McConahy et al., 2004). This number was almost the same as the proportion of variance explained by the number of foods in the diet, number of eating occasions, and body weight combined, suggesting a robust effect of portion size on energy intake.

As shown in Table 1, there are a few experiments investigating the effect of portion size on children's intake. In the first experimental study on this topic, Rolls et al.

(2000) served pre-school children small, medium, and large (376g) portions of a macaroni and cheese entrée at three separate lunches. An effect of portion size was found among 4 to 5-year-old children; their intake of the large portion was 60% greater than in the small portion condition. No significant effect of portion size was observed in 2 to 3-year-old children, suggesting that there may be developmental differences in children's susceptibility to portion size effects. In a second study, Fisher et al. (2003) investigated differences in children's intake of large portions on repeated occasions, and showed that doubling the size of a macaroni and cheese entrée had immediate and persistent effects on 3 to 6-year-old children’s entrée intake at a series of lunches. Relative to an age-appropriate serving, the large portion produced a 25% increase in children’s entrée consumption. These findings were consistent with studies investigating portion size effects on energy intake in adults (Rolls, Morris, & Row, 2002; Diliberti, Bordi, Conklin, Roe, & Rolls, 2004; Rolls, Roe, Kral, Meengs, & Wall, 2004). The third single meal study was designed specifically to investigate age-related effects in children's responses to portion size in a sample of 75 non-Hispanic White children (Fisher, 2007). The children had 29% greater entrée intake when a large portion was provided, in comparison to a reference condition, and this effect did not differ by age groups (2-3 years, 5-6 years, and 8-9 years), demonstrating that children as young as age of 2 were influenced by portion size.

Although the findings of single meal studies provide evidence that large portions affect children’s eating by promoting energy intake at a meal, whether portion size effects continued beyond a single meal was unclear from these studies. Fisher, Arreola, et al., (2007) conducted a within-subjects experimental study with reference and large portion conditions with low-income Hispanic and African-American 5-year-old children and their mothers. Three entrées (lunch, dinner, and breakfast) and an afternoon snack were provided in two portions during two 24h periods: reference size in one condition and large (doubled) in the other. Large portion size of many entrées and a snack served during a day, led to 23% increase in energy intake from those foods. However, significant increases in intake were only found for chicken nuggets and cereal entrées. No compensatory decreases were observed in the intake of other foods. These findings evidenced portion size effects on intake beyond a single meal.

Although the previous studies showed a robust effect of portion size on children's food and energy intake, one study by Leahy, Birch, Fisher and Rolls (2008) did not find portion size effects on intake when 300g and 400g portions of pasta with tomato sauce were offered to children. These contradictory findings may be due to the relatively small differences between two portions; in previous studies large portion sizes were twice as big as small portion sizes. The current study tests how increasing portion size in 60g increments across wide range of portions (100 to 400 g) increases children's entrée intake.

Changes in eating behaviors in response to increasing portion size

In addition to establishing that larger portions promote greater intake, it is important to understand how larger portions affect children's eating behavior to promote greater intake. Behavioral observations of children's response to portion size have investigated whether increases in portion size alter bite size or number of bites of the entrée in the meal. Fisher et al. (2003) found a 25% increase in entrée intake when the portion size was doubled. This increase was associated with increases in children's estimated bite size, with no changes in the total number of bites taken. A second study by Fisher (2007) showed similar results. In this study, the reference and large (doubled) portion sizes of macaroni and cheese were served to 2 to 9-year-old children. Analysis of bite patterns showed a positive relation between estimated bite size and entrée portion size. Findings again indicated that large portions were associated with the changes in estimated bite size with no changes on number of bites. Overall, the findings on children's behavioral responses to portion size are limited to the results of just two studies (see Table 1), and the exact parameters of eating affected by large portions are still unclear. We still do not know why number of bites as a direct measure of eating behavior was unrelated to portion size.

Additional behavioral responses to portion size that could affect intake, including eating rate and eating duration, have not been investigated. Eating rate seems to be a potential contributor to obesity as possible indicator of appetite and satiety sensitivity (Guss & Kissileff, 2000): a higher eating rate is proposed to indicate greater motivation to eat, and bigger reduction in eating rate over the meal is suggested to indicate a stronger response to internal satiety signals. Findings from experimental studies manipulating eating rate revealed that faster eating is associated with greater food intake and higher risk for weight gain (Kaplan, 1980; Spiegel & Jordan, 1978). Obese adults have been shown to have more rapid eating pace in comparison to non-obese adults (Gaul, Craighead, & Mahoney, 1975; Marston, London, Cohen, & Cooper, 1977). Gaul et al. (1975) showed differences between obese and non-obese adults in bite rate, sip rate, and consumatory behaviors. In addition, sucking rate in infancy has been associated with weight gain and later risk of obesity (Stunkard, Berkowitz, Schoeller, Maislin, & Stallings, 2004; Stunkard, Berkowitz, Stallings, & Schoeller, 1999). Similarly, when compared to normal weight 8 to 12-year-old children in a laboratory setting, obese children showed a higher rate of eating, greater bite size, and acceleration of eating towards the end of the meal (Laessle, Uhl, & Lindel, 2001). However, there are no studies investigating how these eating behaviors relate to portion size.

Although previous research has linked larger portions to increased energy intake (Diliberti et al., 2004; Fisher, Arreola et al., 2007; Fisher, Liu et al., 2007; Fisher et al., 2003; Rolls et al., 2002; Rolls et al., 2004; Rolls et al., 2000), evidence is lacking on how larger portion sizes influence children's eating behavior to contribute to the development of obesity. While the obesity epidemic has affected all demographic groups, the increases have been greatest at the upper end of the distribution; overweight children have become markedly heavier in recent decades (Flegal & Troiano, 2000; Jolliffe, 2004; Ogden et al., 2006; Ogden et al., 2008). This pattern of change suggests the possibility that individual differences in children's responsiveness to environmental factors, like portion size, may be linked to obesity risk. The nature of the relation between portion size and weight status could be elucidated if moderating influences of weight status are considered when assessing behavioral responses to portion size.

Table 1

Summary of previous experimental portion size studies on children in which entrée portions were manipulated

Study, year	Sample size	Age (year)	PS range[1]	Weight included as covariate	Weight effects (ME / MOD)	PS effect on intake	Behavioral responses to PS	Self-served
Rolls et al., 2000	32	3-6	3 (S:150g, M:263g, L:376g)	Y	ME:N-sig MOD:N-sig	Sig	N.D.	N.D.
Fisher et al., 2003	31	2-5	2 (S:175g, L:350g)	Y	ME:N-sig MOD:N-sig	Sig	Number of bites Bite size*	Y
Fisher, 2007	75	2-9	2 (S:250g, L:500g)	Y	ME:N-sig MOD:N-sig	Sig	Number of bites Bite size*	Y
Fisher, Arreola et al., 2007	59	5	2 (S and L were varied for offered entrées)[2]	Y	ME:N-sig MOD:N-sig	Sig	N.D.	N.D.
Fisher, Liu et al., 2007	53	5-6	2 (S:250g, L:500g)	Y	ME:N-sig MOD:N-sig	Sig	N.D.	N.D.
Leahy et al., 2008	77	2-5	2 (S:300g, L:400g)	Y	ME:N-sig MOD:N-sig	N-sig	N.D.	N.D.

[1] The included portion sizes are chosen based on their relevance to our study age group (3-5 years old children with an average age of 4.3 years)
[2] The portion size of three entrées (lunch, dinner, and breakfast) and an afternoon snack offered during a 24-h period were of a reference size in small condition and doubled in the large condition.

PS= Portion Size Y = Yes S = Small, M = Medium, L = Large ME= Main effect MOD: Moderation effect N.D. = Not Determined Sig= Significant N-sig=Non-significant
* Significant effect of portion size on eating behavior measurement

Self-served portion and children's responses

Overeating is one of the major contributors to current obesity rates. Findings from experimental studies showed that the tendency to overeat can be explained by exposure to large portions. However a study by Fisher et al. (2003) revealed that when children were allowed to serve themselves from a bowl containing large portions of an entrée, they selected smaller portions, similar to reference portions, and ate significantly less than when served large portions. These findings suggested that giving children the opportunity to self-serve the food may reduce intake and diminish the adverse effects of exposure to large portions of energy dense foods. This study (Fisher et al., 2003) was partially replicated by Fisher (2007), in a study of 2 to 9-year-old children, intake in the self-selected condition was not different from that in the large portion condition when all the children were included in the analysis. However, self-serving led to decreased intake for children who ate more when served the large portion. These findings showed that that allowing children to self-serve portion size may specifically benefit children who overeat when served large portions. However there have only been two studies investigating self-serving effects on children's intake, and weight influences on children's response to self-served conditions have not been evaluated.

Specific Aims

This research has three specific aims:

1. To test a) whether increasing portion size increased entrée intake, number of entrée bites, time spent eating the entrée, or estimated bite size, b) whether these relations differed by children's weight status and c) whether number of entrée bites, or time spent eating the entrée predicted children's entrée intake;

2. to investigate a) changes in eating rate from the beginning to the end of a lunch session and b) whether changes in eating rate were related to children's weight status; and

3. to test a) whether self-served entrée size was related to children's weight status, and whether consumption differed between 400g condition and self-served condition with regards to entrée consumption and b) whether children's estimated bite size or number of bites differed by weight status during this condition.

Chapter 2

Method

Participants

Participants were 21 children aged 3 to 5 years attending full-day day-care at the Child Development Laboratory located at The Pennsylvania State University, University Park. Children were recruited for participation in the study through letters to their parents. Of the 21 children who were initially recruited for the study, four children were excluded from the analysis because they did not meet the predetermined inclusion criteria (i.e., by having food intolerance to study foods, chronic illness influencing food intake, extended absences, consistently consuming less than 50g of the entrée, or disliking the entrée: ranking the entrée as “yucky”). As shown in Table 2, the final sample included 17 children (seven boys and ten girls) with a mean (± SD) age of 51.4 ± 6 months (range = 38.9-62.4) and a mean weight of 18.2 ± 3.4 kg (range = 13.9-27.4). Children were from well-educated families; median education level was a Master’s degree (18+ years) for mothers and a PhD (20+ years) for fathers. Most of the families (60%) reported incomes greater than $50,000. Parents provided written consent for their child’s participation in the study. The Pennsylvania State University Institutional Review Board approved all study procedures.

Table 2

Background Characteristics at Study Entry (*n*=17)

Variable	Total ± SD	BMI Percentiles≥85th	BMI Percentiles<85th
Age (months)	51.6 ± 6	50.4 ± 7	51.6 ± 5
Sex	10 girls, 7 boys	2 girls, 4 boys	8 girls, 3 boys
Weight	18.2 ± 3	21.2 ± 3	16.6 ± 2
Height	103.6 ± 5	106.3 ± 5	102.2 ± 5
BMI Percentiles[1]	74.6 ± 19	94.4 ± 5	63.7 ± 13

[1] Percentiles were calculated using the CDC growth charts; BMI Percentiles at or above 85th percentile was defined as overweight in this study

Design

In this within-subject repeated measure design, children participated in ten sessions (see Table 3). The first session was used for familiarization, preference assessments, and anthropometric measurements. Familiarization continued into the second week. During this session, each child was served the standard test meal including 340g portion of the entrée to familiarize children with the staff, food, serving procedures, and the setting. Participants consumed experimental meals varying in portion size during weeks three through eight. Weeks nine and week ten were a makeup session and self-serving week, respectively. The lunch menu included an entrée that was manipulated in portion size and fixed portions of side dishes. Portion sizes of the entrée were presented to the children in one random order: 220g, 280g, 100g, 340g, 160g and 400g, respectively (Table 3). Both classrooms received the same order of portions each week. Foods were pre- and post-weighed at each lunch to measure intake. Estimated bite size and number of entrée bites were coded from videotapes of the lunch sessions.

Table 3

Experimental timeline

Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
FSTE	FSTE	220g	280g	100g	340g	160g	400g	Make-up	SS
Preference									
HW									

FSTE = Familiarization Standard Test Meal of the Entrée

HW = Height and Weight measurements

SS = Self-Served condition

Measures

Food intake was measured during each of the six test lunches and one self-served lunch. Children in each of the two classrooms were served their lunch at their regularly scheduled time at a dining area separate from their classroom, which was decorated in a child-friendly manner with a jungle theme. Data collection occurred during two consecutive lunch sessions on two days each week. Children ate lunch with children from their own classroom; half of the children from each classroom were accommodated per day. The dining area contained two tables of two to four children, and two trained staff recorded any comments children made about the food. Video cameras on tripods were set up around the tables to record children's eating behavior. Two cameras were used for each table and positioned so that each child appeared in two camera views, so were videotaped from two different angles in order to most accurately record actual number of entrée bites. Children were identified by a visual animal symbol and not by name, thereby preserving the anonymity of the participants, and these animal figures were used to identify the children in the videos. Tables were set with identically arranged trays containing the entrée and the other standard menu items, with uniform containers used at each meal. Children were asked to eat as much as or as little as they wanted, not to share their food with others, and to remain in their seats for the duration of the lunch period. Trained research staff directed any food-related conversations to non-food topics. Children were given 20 minutes for lunch and were reminded when five minutes remained. When lunch was finished, spilled or dropped foods were returned to their respective dishes for post-weighing. Spilled milk was cleaned up with pre-weighed paper towels, and milk intake was determined by subtracting the dry towels' weight from that of the wet towels. To measure the amount of food consumed, all food items were weighed before and after the meal to the nearest 0.1 g using digital scale.

Experimental menu

Macaroni and cheese (Stouffer's, Solon, Ohio) with an energy density of 1.52 kcal/g (6.36 KJ/g) was the entrée served throughout the study. Six entrée portions (100, 160, 220, 280, 340 and 400 g) were chosen to represent a wide range of average macaroni and cheese intakes in pre-school children based upon data from CSFII, 1994-1996 (Smiciklas-Wright, Mitchell, Mickle, Goldman, & Cook, 2003). The smallest portion (100g) corresponded to the 25^{th}-50^{th} percentiles of intake and the largest portion (400g) corresponded to the 95^{th} percentile for 2 to 5-year-old children in CSFII data set.

A standardized lunch menu that differed only in entrée portion size was served to the participants. Other foods in the standard menu included green beans (85g) with whipped butter (5g), unsweetened applesauce (250g), a whole wheat roll (35g), and 2% milk (244g). Total energy offered at lunch was generous compared with estimated energy requirements (EERs) for a day based on sex, age, measured weight and height, and an assumed average physical activity level (Food and Nutrition Board, 2002). Total energy offered to children ranging from 525 kcal (~40% of estimated daily requirements) at the meal with the 100g entrée to 981 kcal (~70% of estimated daily requirements) at the meal with the 400g entrée. Children's preferences for the entrée were assessed, and the 17 children who rated the entrée as "yummy" or "just okay" were included in the study.

Self-Served portion of the entrée

As shown in Table 3, following the six weeks of data collection when children were offered lunch with entrée differing in portion size, children were offered a lunch in which they self-served portions of the entrée from a serving dish at a meal. Tables were set with individual trays including the same gram portions of all side dish items from the standard menu and a pre-weighed empty plate. Each child had an individual serving dish, containing 400g of the entrée near their lunch tray. Children were instructed to serve themselves as much of the entrée as they wanted, and to eat as much as or as little as they would like, and not to share their food with peers. Children's intake was measured by weighing how much each child consumed from self-served plates. To calculate the total amount of entrée served, grams of entrée consumed were added to the remaining grams of entrée on the plate. Macaroni and cheese was also scraped from serving spoons and added to the calculation.

Behavioral assessment of children's bites patterns and time spent eating the entrée

Each child's eating behavior was recorded by two cameras from two sides of the table to ensure that all children's eating behavior was recorded throughout the lunch session; time elapsed during lunch was recorded on videotapes to the nearest tenth of a second. Trained coders reviewed tapes and recorded the number of bites of entrée taken by each child at each meal session including the self-served session. Number of entrée bites was coded as any instance of food to mouth contact and if it was more than three times from one spoon the number of entrée bites coded as three; inter-rater reliability was .99. Estimated bite size of an entrée, defined as total grams of entrée consumed divided by total number of entrée bites taken in each portion condition, was also analyzed as an indirect measure of eating behavior.

Time spent eating the entrée was calculated by subtracting the time at the first bite from the time at which the last bite of the entrée was consumed. Number of bites per minute was measured for 340g portion during the entire 20 minutes of lunch period and changes in eating rate were investigated across four five-minute intervals. This condition was chosen from the various portion sizes because it was the smallest portion size where no children finished the entire portion. Thus, children's intake was not limited by portion size and so the analysis of changes in eating rate differences based on weight status could be more reliable.

Anthropometric Measures

A trained staff member measured children's heights and weights following standard procedures (Lohmann, Roche, & Martorell, 1988). Height was measured in duplicate to the nearest tenth of a centimeter using a stadiometer. Weight was measured in duplicate to the nearest tenth of a kilogram using an electronic scale. Average of height and weight were included in the analysis. The CDC Growth Charts (Kuczmarski et al., 2000) were used to determine age- and sex-specific BMI percentiles, and children with a BMI at or above the 85th percentile for age and sex were considered overweight.

Statistical Analysis

All analyses were conducted using SAS Version 9.1 (SAS Institute Inc, Cary, NC). Results were considered significant at $p<.05$. The study was powered to detect a 50g increase in entrée intake, assuming a similar variance to previous portion size studies, at an alpha of .05 and power =.80, assuming six within subject measures that are mildly correlated ($r=.60$). With these assumptions, 14 subjects were needed to detect a statistically significant increase in entrée intake when comparing 100 to 400 g portions. Due to the observed significance in the findings the retrospective power analysis was not conducted.

Specific Aim 1: to test a) whether increasing portion size increased entrée intake, number of entrée bites, time spent eating the entrée, or estimated bite size b) whether these relations differed by children's weight status and c) whether number of entrée bites, time spent eating the entrée predicted children's entrée intake

A repeated measures analysis of (Proc Mixed, SAS) was conducted to determine the effect of portion size on entrée intake, number of entrée bite, time spent eating the entrée, or estimated bite size. BMI percentile as continuous variable was considered as a covariate in the analysis in order to investigate whether these relations differed by weight status. The analysis also was done considering BMI percentiles as categorical variable: BMI percentiles ≥ 85^{th} (overweight group) and BMI percentiles < 85^{th} (non-overweight group). To adjust the intakes for weight status, mixed model analysis of covariance was conducted for entrée intake including the new variable that was gram entrée intake divided by child's weight (kg) to see whether there was difference in entrée intake over and above the difference in body weight. The additional covariates tested included age and sex. Week, lunch session, classroom, and lunch table were accounted for as random effects in the models. Hierarchical regression was used to explain how much number of entrée bites, time spent eating the entrée (higher to lower priority, respectively) contribute to entrée intake. Because most children ate the entire portion of the entrée in the two smallest portion sizes, the variance in entrée intake in these two conditions was substantially smaller in this condition than in the four larger portion size conditions. The percentage of children who consumed ≥ 95% of the portion size offered was: 81% for 100g portion and 76% for 160g portions. These analyses were done for the full range of portions from 100 to 400 g, and given the unequal variance the analysis were also conducted for the range of portions from 220 to 440 g.

Specific Aim 2: to investigate a) changes in eating rate from the beginning to the end of a lunch session and b) whether changes in eating rate were related to children's weight status

The 20 minute duration of the 340g lunch period was divided into four five-minute intervals: 0-5 minutes, 5-10 minutes, 10-15 minutes and 15-20 minutes. Number of bites per min in each interval was counted to determine eating rate. Repeated measures analysis of variance was used to test whether there was a time effect on children's eating rate during the 340g condition and whether this differed by BMI percentiles. The effect of BMI percentiles was investigated as categorical variable: overweight group and non-overweight group.

Specific Aim 3: to test a) whether self-served entrée size was related to children's weight status, and whether there was any difference between 400g condition and self-served condition with regards to entrée consumption and b) whether children's estimated bite size or number of bites differed by weight status during this condition.

Analysis of variance was conducted to examine whether amount of the entrée children served themselves and amount of the entrée they ate from their served plates were predicted by BMI percentiles group. The influence of BMI percentiles group was also assessed to determine whether there was a difference in the grams of entrée served, eaten or in the proportion of grams eaten to served, between overweight and non-overweight children. Analysis of variance was also used to find whether there was any entrée consumption difference between 400g condition and self-served condition among whole sample, weight groups and groups of non-responders (those whose entrée intake in 400 condition was similar to or less than entrée intake in 220 condition) and responders (those whose entrée intake in 400g was greater than 220g portion). Children's intake in 220g was compared with 400g because it was very close to the portions examined in Fisher (2007) study. In addition, analysis of variance was used to test whether there were any relations between BMI percentiles group and number of entrée bites or estimated bite size.

Chapter 3

Results

Specific Aim 1: to test a) whether increasing portion size increased children's entrée intake, number of entrée bites, time spent eating the entrée or estimated bite size, b) whether these relations differed by children's weight status and c) whether number of entrée bites, and time spent eating the entrée predicted children's entrée intake

When increasing the portion size from 100 to 400 g, a significant interaction was found between BMI percentiles and portion size to predict entrée consumption (F=12.63, p<.01); children with higher BMI percentiles showed greater increases in entrée consumption when the portion size increased. The results were similar when BMI percentiles were analyzed as a continuous variable (F=13.89, p<.01). Given the low variability between participants within the two smallest portions, the analyses were also conducted excluding the 100g and 160g portions; the interaction of BMI percentiles group and portion size was no longer significant (F=1.49, p=.23). However, main effects of BMI percentiles and portion size were remained significant predictors of gram entrée intake (F=8.16, p=.01 and F=38.85, p<.01). The similar results were found for BMI percentiles as continuous variable. When entrée intake was adjusted for child's body weight, the interaction between portion size and BMI percentiles became non-significant (F=2.24, p=.05) and BMI percentiles was no longer a significant covariate (F=.13, p=.72), however, portion size was still significant predictor of entrée intake before (F=33.18, p<.01) and after (F=24.12, p<.01) exclusion of 100 and 160g portions. In addition, as shown in Table 4, gram entrée intake was found to be highly correlated with total gram food intake during lunch across six portion sizes (r = .58, p<.01); increasing entrée intake in response to increasing portion size was related to increases in total food intake. The results on the effects of portion size on intake of other foods and total energy intake at the meal are presented elsewhere (Savage et al., 2009).

Table 4

Mean ± SD gram entrée intake and gram total food intake at lunch across six portion sizes (N=17)

Portion	Entrée intake (g)	Total food intake (g)
100g	95.2 ± 6	366.8 ± 99.8
160g	153.4 ± 8.1	419.8 ± 92.2
220g	171.9 ± 45.6	438.1 ± 130.5
280g	198.9 ± 57.7	434.9 ± 140.3
340g	234.3 ± 76.5	459.1 ± 153.3
400g	256.4 ± 55.4	455.1 ± 88.5

As shown in Figure 1, a significant interaction was found between BMI percentiles and portion size on number of entrée bites (F=4.57, p<.05), such that children with higher BMI percentiles took a higher number of entrée bites when portion size increased. Analyzing BMI percentiles as continuous variable also showed a similar result; there was a significant interaction between portion size and BMI percentiles (F=5.65, p<.05). No significant interactions were found between BMI percentiles and portion size to predict time spent eating the entrée or estimated bite size. However as shown in Figure 1, there was a significant main effect of portion size on time spent eating the entrée (F=34.60, p<.01), estimated bite size (F=5.03, p<.05), entrée intake (F=374.32, p<.01) and number of entrée bites (F=38.67, p<.01). When the 100 and 160 g portions excluded, results changed to be non-significant for time spent eating the entrée and estimated bite size (*F*=.05, *p*=.82 and *F*=.01, *p*=.92, respectively). In addition, the interaction between portion size and BMI percentiles became non-significant (*F*=1.85, *p*=.18). However a significant main effect of portion size on number of bites was still apparent (*F*=17.33, *p*<.01).

The analysis of sex and age as covariates showed that these two factors were not related to entrée intake, number of entrée bites, time spent eating the entrée and estimated bite size; although the proportion of boys to the girls in overweight and non-overweight group was different (see Table 2), when sex and BMI percentiles were included in the model, BMI percentiles was the only significant predictor of entrée intake (*F*=11.02, *p*<.01) while the effect of sex was non-significant (*F*=.25, *p*=.62). Order was included in the model as random effect and the results showed that when order (week) is included, the effect of portion size on entrée intake remained significant (*F*=136.75, *p*<.01) while the effect of week was non-significant (*F*=.03, *p*=.85).

To determine whether number of entrée bites, and time spent eating the entrée predicted entrée intake, hierarchical regression analyses was used and the results showed the influence of number of entrée bites (R^2 =.40, *p*<.01), time spent eating the entrée (R^2 =.05, *p*<.01).

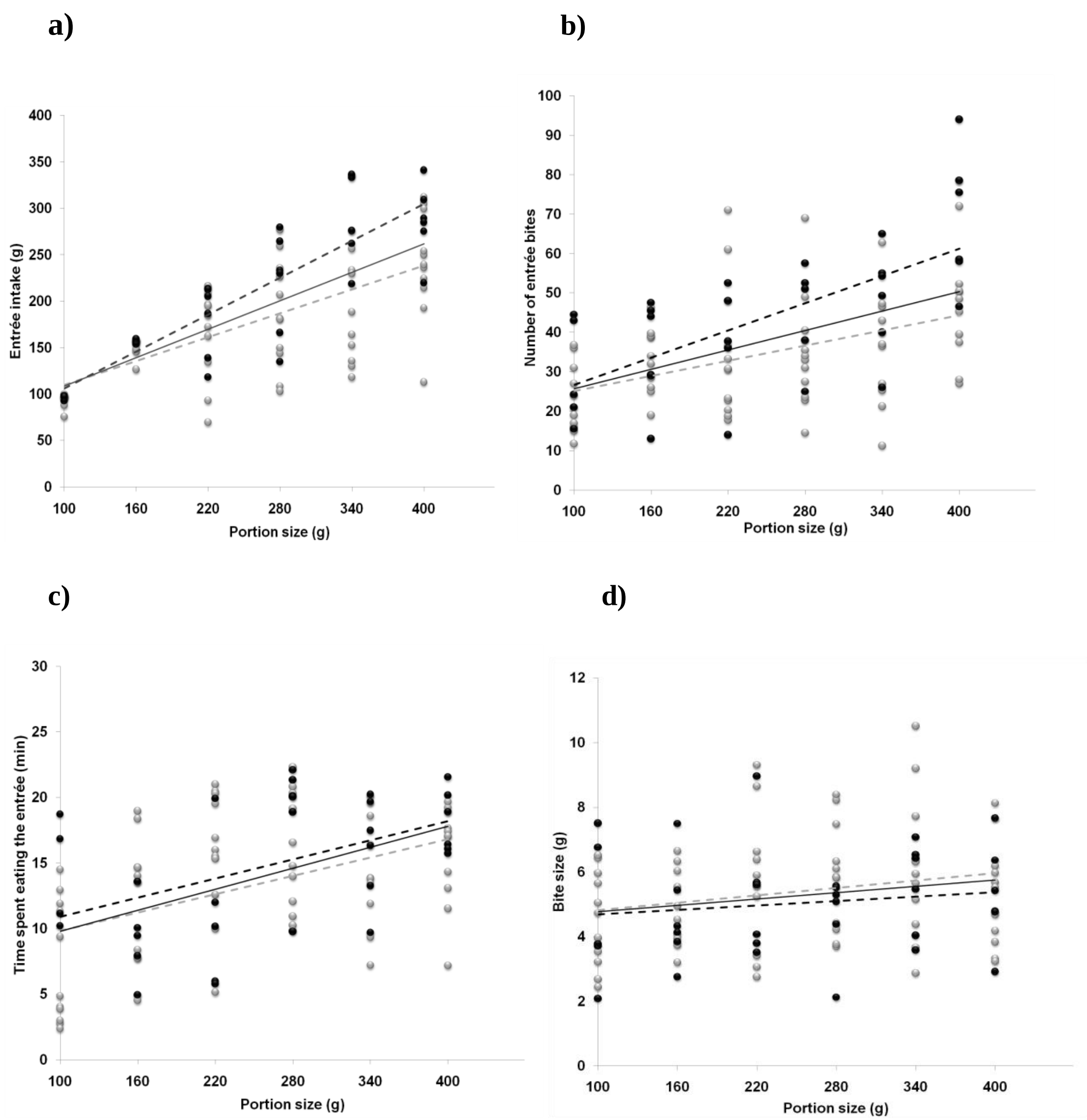

Figure 1. Portion size effects on a) entrée intake, b) number of entrée bites, c) time spent eating the entrée and d) estimated bite size for overweight (●) and non-overweight (●) children (N=6 and N=11, respectively). The main effect of portion size was moderated by weight status for entrée intake (*p*<.01) and number of entrée bites (*p*<.05).

Specific Aim 2: to investigate a) changes in eating rate from the beginning to the end of a lunch session and b) whether changes in eating rate were related to children's weight status

As shown in Figure 2, there was a significant interaction with BMI percentiles group (F=8.62, p<.01): During 20 minutes of lunch period, eating rate did not decline significantly for the overweight group, while the non-overweight children did show a decreased eating rate over time.

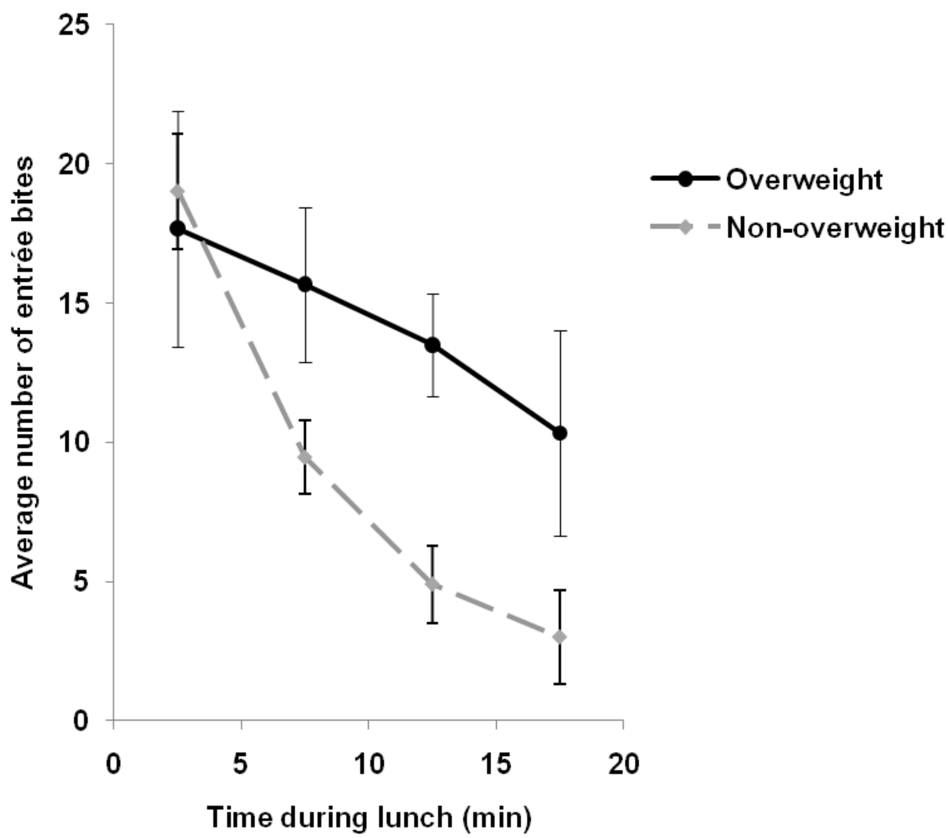

Figure 2**.** Changes in eating rate during lunch differed for overweight and non-overweight children. ANOVA was used to test the effect of time on eating rate based on BMI percentiles group. Data are presented as means ± SEMs; Overweight group (N=6) showed non-decelerating eating rate, while the non-overweight group (N=11) did exhibit a decrease in eating rate over the 20 minutes lunch period p<.01

Specific Aim 3: to test a) whether self-served entrée size was related to children's weight status, and whether there was any difference between 400g condition and self-served condition with regards to entrée consumption

Total sample in self-served condition decreased to 16 due to the absence of one child. As shown in Figure 3, although overweight children served themselves more total grams of macaroni and cheese than non-overweight children, this difference was not significant (F=2.58, p=.13). However overweight children ate more of the entrée in the self-served condition than non-overweight children (F=6.63, p<.05). There was also a significant linear relationship between BMI percentiles and total grams entrée eaten (F=2.89, p<.05). There was no significant difference between overweight and non-overweight children on the proportion of "macaroni and cheese intake" to "macaroni and cheese served" (F=3.21, p=.09). Further analysis revealed that there were some plate cleaner children in both groups who consumed ≥ 95% of the grams amount that they served themselves; Fisher's exact test analysis showed that 3 out of 5 (60%) overweight children and 2 out of 11 (18%) non-overweight children were plate cleaners in the self-served condition.

Total grams of the entrée eaten in self-served condition were not different from consumption in the 400g condition (F=.64, p=.44). Thus, similar to Fisher (2007) study, the analysis was also conducted to see whether there were groups of non-responders and responders to portion size and whether children's intake of self-served portions in these two groups differed from their intake in 400g condition. The findings showed that 95% of children (16 out of 17) were responders to portion size and their self-served entrée intake was not different from 400g condition's entrée intake. In addition, children's intake in self-served condition was compared to 400g condition based on weight status. The results showed no difference between overweight or non-overweight children's consumption of the entrée in 400g and self-served condition (F=.39, p=.55 and F=1.30, p=.27, respectively).

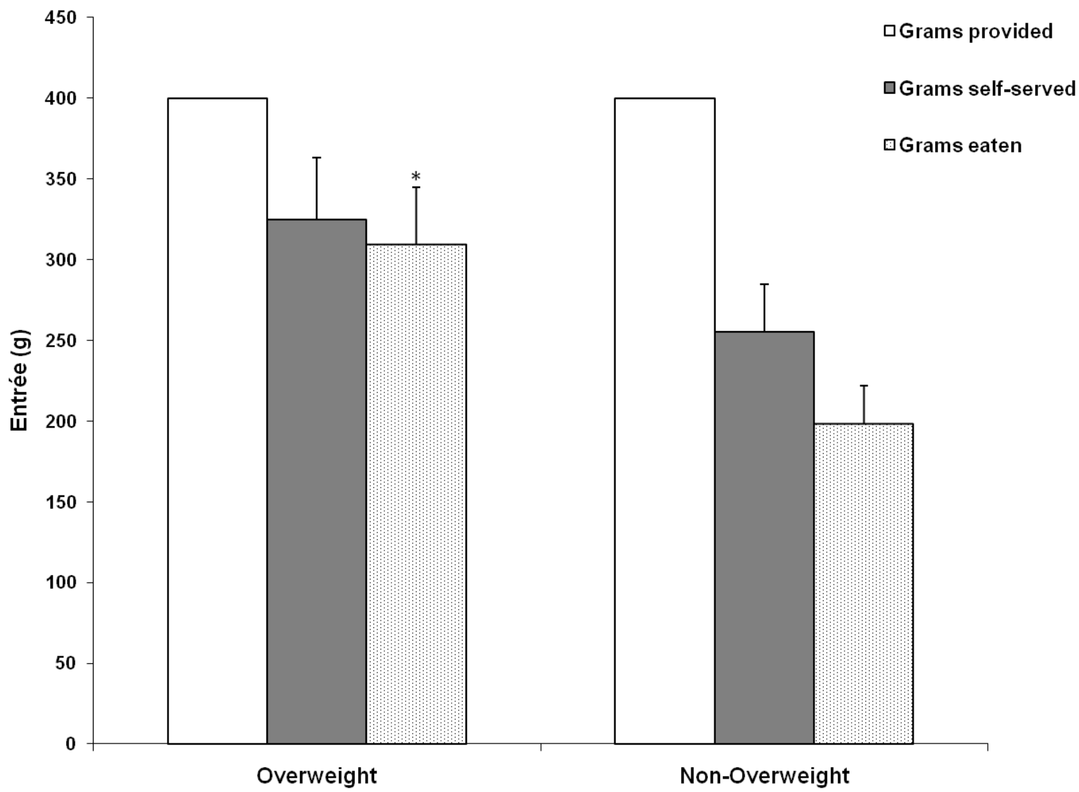

Figure 3. Overweight children (N=6) consumed significantly more entrée in the self-served condition than non-overweight (N=10) children. * significantly greater than non-overweight children for grams entrée eaten, p<.05.

Specific Aim 3: b) whether children's number of entrée bites or estimated bite size differed by weight status during self-served condition

Number of entrée bites during the self-served condition was differed by children's BMI percentiles (F=16.23, p<01). Figure 4, shows that overweight children had higher average number of entrée bites (69±14) than non-overweight children (35±16). Estimated bite size was not associated with BMI percentiles (F=1.54, p=.23).

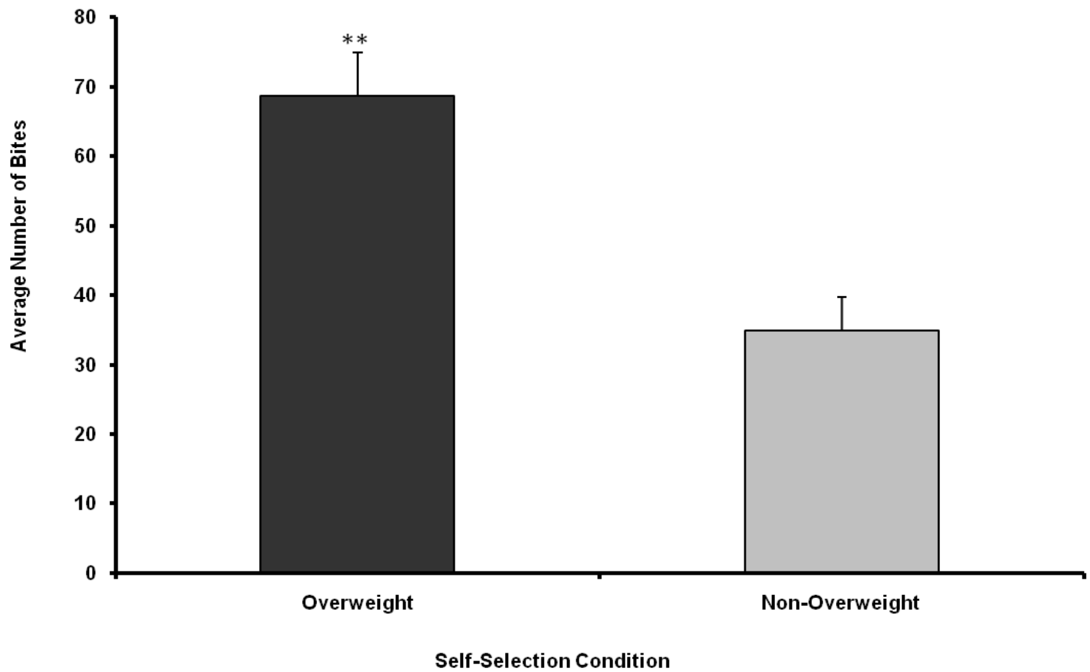

Figure 4. The average number of bites (±SEM) for overweight (N=6) and non-overweight children (N=10) in self-served condition; ** significantly higher than non-overweight p<.01

Chapter 4

Discussion

This study shows that increasing the portion size increased children's entrée intake, number of entrée bites, time spent eating the entrée, and estimated bite size. The effect of portion size on entrée intake and on the number of entrée bites was moderated by BMI percentiles, with overweight children showing greater increases in entrée intake and number of entrée bites. However, children's time spent eating the entrée and estimated bite size across a wide range of portions did not differ by BMI percentiles. Number of entrée bites, and time spent eating the entrée were independent predictors of children's entrée intake. Differences in eating behavior by weight status were also observed with non-overweight children showing a deceleration of eating rate over the course of the meal, while overweight children's rate of intake did not slow significantly over time. Further weight-related eating patterns were also found in the self-served condition, revealing greater food intake and a higher number of entrée bites among overweight children. In this study, self-serving did not mitigate the impact of large portions. There was no difference in intake when comparing the conditions in which the 400g portion was served on the plate or that where children were able to self-serve the entrée from individual 400g serving bowls.

BMI percentiles: a potential moderator of children's responses to increasing portion size across a wide range of portions

Increasing the portion size of the entrée from 220 to 400 g led to a 49% increase in gram intake of the entrée. This increase corresponded with higher energy intake; these results are discussed elsewhere (Savage et al., 2009). The significant effect of portion size on intake observed in our study is consistent with previous experimental studies in which children's meal consumption increased when a larger portion size of a main lunch or dinner entrée was provided (Fisher, 2007; Fisher, Arreola et al., 2007; Fisher, Liu et al., 2007; Fisher et al., 2003). Our findings, based on six portion sizes, which included portions both smaller and larger than reference portions for children of this age, also provided evidence that children's weight status moderated the relation between portion size and gram food intake of the entrée. Children with higher BMI percentiles showed greater increases in food intake as the portion size increased, suggesting that heavier children may be more susceptible to overeating in an environment that promotes excess intake through the availability of large portion sizes. However, it is also possible that overweight children's greater intake might have been due to their greater energy needs. When intake was adjusted for weight (kg), the interaction between BMI percentiles and portion size was eliminated which implies that the impact of portion size on intake did not differ at different levels of weight status. However, adjusting on a per kg basis doesn't take into account individual difference in height, percent fat, or lean body mass, which would also affect expenditure and how much needs to be consumed for children with different body size.

We also conducted the analysis removing 100g and 160g portions. Although based on population based data, the smallest portions should have been adequate but because nearly all children consumed ≥ 95% of the two smallest portions it was not clear whether their intake was limited by portions or whether it was adequate. After deleting the two smallest portions, in which the variance in intake was low, the portion size interaction with BMI percentiles was eliminated but the significant BMI percentiles main effect on entrée intake suggests that heavier children eat more across 220 to 400 g portion sizes. BMI percentiles' main effect was also eliminated when weight status was adjusted in entrée intake analysis. However the effect of portion size on entrée intake remained significant but since the current experiment is not a longitudinal study and weight changes based on greater intake in large portions were not measured, we cannot conclude that large portions cause greater weight gain. It highlights the need for longitudinal studies focusing on portion size effects on weight gain across longer periods of time.

In the present study, we assessed the effect of a wide range of portions on behavioral responses including number of entrée bites, time spent eating the entrée, and estimated bite size. The problems with unequal variances that were encountered with the consumption data did not arise for these eating behavior variables. Thus, the results based on all six portion sizes are included here. The significant interaction between portion size and weight status on number of entrée bites indicated that children with higher BMI percentiles were more responsive to the larger portions by taking more bites and that this was reflected in the higher gram intake of the entrée. Previous studies investigating eating behavior among overweight and non-overweight children and adults have shown mixed findings with respect to the number of bites taken at a meal; some studies have shown a higher number of bites among overweight individuals (Drabman, Cordua, Hammer, Jarvie, & Horton, 1979; Drabman, Hammer, & Jarvie, 1977; Gaul et al., 1975; Llewellyn, van Jaarsveld, Boniface, Carnell, & Wardle, 2008; Marston et al., 1977; Marston, London, & Cooper, 1976) whereas some studies have not shown such results, finding only larger bite size among overweight individuals (Dodd, Birky, & Stalling, 1976) or no differences in bite patterns among overweight and non-overweight participants (Mahoney, 1975; Spiegel, Kaplan, Tomassini, & Stellar, 1993). These mixed findings show a need for further studies of weight-related ingestive behaviors as well as comprehensive research on behavioral responses to portion size to fully understand the manner in which portion size changes the microstructure of eating.

In the total sample, increasing portion size increased the number of entrée bites, time spent eating the entrée, and estimated bite size, such that children took more and larger bites and spent a longer time eating the entrée when offered larger portions. Our significant findings on the effect of portion size on estimated bite size is consistent with previous studies (Fisher, 2007; Fisher et al., 2003), showing larger portions increase children's bite size. However, in the current study, the effect of portion size on number of entrée bites is also observed, which has not been seen in previous research probably due to smaller range of portions offered. This is the first portion size study on children revealing two different bite related styles of eating in response to large portions: increasing number of bites as well as estimated bite size.

We found each of number of entrée bites and time spent eating the entrée were independently related to entrée consumption. This, in addition to our findings of portion size effects on the three eating behavior measurements, suggests that children's higher entrée intake in response to increasing the portion size can be explained by changes in their eating behaviors, such that children increase their entrée intake when the portion size increases by eating longer, taking a greater number of bites, and increasing bite size. However making conclusion on estimated bite size is limited because it is calculated from dividing entrée intake and as we found the entrée intake was limited by portions in two smallest portions which can also explain why removing 100g and 160g portions changed the portion size effects on estimated bite size to non-significant. For future studies we suggest measuring bite size as a direct measurement of eating behavior across portion sizes; previous studies assessing eating behavior in humans, using cumulative food intake curves have used Universal Eating Monitor (UEM) to assess bite size directly (Westerterp-Plantenga, 2000). UEM consists of a hidden scale embedded in a table underneath the plate that the participant eats from. Each time a bite is taken by the participant, the new weight of the plate is recorded by the computer connected to the scale. The change in the weight of the plate as each bite is taken could be used in future portion size studies to measure bite size directly.

Eating rate: A possible explanation why overweight children eat more in response to large portions

The findings of the first aim showed a higher number of entrée bites among children with higher BMI percentiles, implying that children may also have a different rate of eating during the course of a meal based on their weight status. Assessment of eating rate by weight status revealed different patterns: during the first five minutes of the lunch, both overweight and non-overweight children's eating rates were similar, but during the second time interval, non-overweight children's eating rate began to decline showing a significant decrease in their eating rate. This reduction in eating rate continued to the end of the meal for non-overweight children whereas overweight children's eating rate did not decrease significantly over the 20 minutes meal. Eating deceleration in our study differed by BMI percentiles level, a finding that is consistent with previous laboratory studies showing that obese individuals have higher eating rate (Barkeling, Ekman, & Rossner, 1992; Lindgren et al., 2000).

Studies investigating eating rate have used eating rate changes during the course of a meal as an indicator of satiation (Barkeling, Rossner, & Sjoberg, 1995; Meyer & Pudel, 1972). Satiation is the process that brings a meal to an end. The non-decelerated eating rate observed among the overweight children in the present study could also indicate differences between normal and overweight children's satiation during the meal. The prolonged initial eating rate observed in the overweight children could potentially explain why overweight children tend to eat more when large portions of foods are available and why they have been proposed to be more susceptible to overeating in obesogenic environments (Flegal & Troiano, 2000; Jolliffe, 2004; Ogden et al., 2006; Ogden et al., 2008). Our findings on 340g portion showed different changes in eating rate among overweight and non-overweight children which might be different for other portion sizes. For future studies we suggest looking at changes in eating rate across wide range of portions and their relations with weight status to better elucidate children's internal responses to satiation signals when the portion size varies.

Allowing children to self-serve portions may not reduce the adverse effects of exposure to large portions

The third aim was to investigate differences between overweight and non-overweight children in the self-served condition, with respect to how much they served themselves from the serving bowl, or how much they ate from the served plate. There were no significant differences between BMI percentiles groups in the amount of entrée children served themselves. However, overweight children did consume more grams of the entrée in the self-served condition compared to the non-overweight children.

To test whether weight status moderated children's responses to the portion of macaroni and cheese that was self-served, we compared the BMI percentiles groups on the proportion of grams of macaroni and cheese consumed to grams served. We hypothesized that overweight children would be more responsive to the macaroni and cheese self-served on their plates. However, the proportion of entrée consumed to the grams served did not differ between the two BMI percentiles groups mainly due to the presence of plate cleaners in both groups.

Previous studies on self-selected portion size were focused on testing whether self-serving mitigated the effects of large portions on intake. The findings of the current study are not consistent with those of previous studies (Fisher, 2007; Fisher et al., 2003). In the study by Fisher et al. (2003) self-serving led to reduction in intake among all the children in the experiment and in another study by Fisher (2007), it was shown that allowing children to serve themselves benefited children who were at risk of overeating in response to large portions. However, in the present study, there was no difference in intake when comparing the standard 400g plated condition to the self-served condition in which a 400g serving bowl was offered. In addition all except one of the children in current study were responders to portion size, and these responders to portion size did not show a reduction intake when they were allowed to serve themselves. These non-significant results apply to both the overall sample and overweight and non-overweight groups. Although these findings contradict Fisher (2003) and Fisher et al. (2007) studies, our findings are consistent with a between-subject adult study, in which the way pasta served to adults did not significantly affect their intake (Rolls et al., 2002). The current findings fail to provide additional support for an intake-reducing effect of self-serving on children in general or specifically on responder to portion size or overweight children. However, due to the small sample size, the generalizability of the current finding is limited. Interpretation of the self-served vs. portion size manipulation condition is also limited because the design did not control for the effect of order.

The second part of the third aim of this study was to investigate children's behavioral responses to a self-served condition based on their BMI percentiles group membership. The results of the self-served condition were similar to those from the portion size manipulation in which greater entrée intake and greater number of bites were found among children with higher BMI percentiles. These results confirm our primary findings on behavioral differences based on weight status when large portions are available; thus we suggest that children in upper levels of BMI percentiles categories are more responsive to portion size and take more bites, regardless of serving method. Based on our findings, allowing children to serve themselves would not protect them against adverse effects of large portions of energy dense foods they are exposed to in everyday life.

This study has a number of strengths, as well as limitations, which should be considered when interpreting the results and their implications for the effects of portion size on childhood obesity. Strengths include 1) a wide range of portion sizes, 2) direct observational assessment of eating behaviors including number of entrée bites and time spent eating the entrée, and 3) the experimental design of the study, allowing conclusions about effects of portion size on food consumption and eating behaviors. The limitations of our research include the small sample size and homogeneity of the sample of children participating in this study; these restrict the generalizability of the findings. Including only one order in the experimental design is also a limitation: in one previous study, children's intake of a fixed portion of macaroni and cheese increased significantly with repeated testing (Leahy, Birch & Rolls, 2008). Although acknowledging that portion size was confounded with order, but when order was included in the model testing portion size effects, only portion size remained a significant predictor. Another limitation of our study is that the laboratory settings limits conclusions about portion size effects in free living environments. However, the laboratory setting reduced peer or family related influences such as modeling, which could have affected with the portion size effects on children's food consumption.

Conclusions

Large portions of energy-dense foods have been shown to promote obesity by increasing food and energy intake in young children. The present study showed that increasing portion size across a wide range of portions increased children's entrée intake via affects of eating behavior including increases in the number of entrée bites, and time spent eating the entrée. In addition, there was a moderating effect of weight status on number of bites, suggesting that children with higher BMI percentiles may be more responsive to the larger portions by taking greater number of bites. Regarding eating rate, different patterns were observed over the course of the meal, such that non-overweight children showed a decreasing trend in eating rate while overweight children failed to show deceleration in eating rate toward the end of the meal. This pattern of intake observed among overweight children suggests that the satiation process may be impaired among these children, which may put them at risk for overeating. Thus, providing large portions of energy dense foods may promote higher intake among overweight children, which could result in higher weight gain among children in upper BMI percentiles.

In contrast with previous findings, this study does not support the hypothesis that allowing children to self-serve portions mitigates the influence of large portions on children's intake. Rather, the present findings suggest that serving age-appropriate portions might be an effective strategy. However, in the current obesogenic environment with its high availability of large portions there is a need for additional intervention studies to reduce the adverse effects of exposure to large portions. Based on our findings, possible intervention strategies could include teaching children to choose and eat appropriate portions, take fewer and smaller bites, and to improve their eating rate by focusing on hunger and satiation cues which can lead to better self-regulation of energy intake, an approach previously explored by Johnson (Johnson, 2000). This requires parents and caregivers are also informed about age-appropriate portions, in order to create feeding environments providing age-appropriate portions of healthy foods, encouraging children following healthy eating behaviors such as taking fewer and smaller bites and focusing on their internal cues of satiation, and lastly, by serving as positive role models of these eating behaviors. In conclusion, this study suggests that increasing portion size may increase children's intake via changes in number of entrée bites and time spent eating the entrée and also suggests the possibility that children with higher BMI percentiles might be more susceptible to overeating by taking greater number of bites when served larger portions.

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