

Current Research

Relationship between Portion Size and Energy Intake among Infants and Toddlers: Evidence of Self-Regulation

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ABSTRACT

Objectives To assess whether dietary intakes of infants and young toddlers show evidence of energy self-regulation.

Design Data from 24-hour recalls collected in the 2002 Feeding Infants and Toddlers Study were analyzed. Multivariate regressions were used to explore the relationship between portion size and usual energy intake as well as the relationship between portion size, number of eating occasions, number of unique foods, and energy density.

Subjects/setting A national random sample of 3,022 US infants and toddlers 4 to 24 months of age.

Statistical analyses performed To measure variability in portion size, an average portion size *z* score was computed for each child in the sample, across 45 different food groups. The number of eating occasions was defined as the total number of times a child had anything to eat or drink during the day, excluding eating occasions that included only water and/or supplements. The total number of unique foods in a day was defined as the number of unique food codes included in the 24-hour recall, and energy density was computed as kilocalories/gram, including all foods, beverages, and water. Linear regression models were used to assess the effect of portion size and other self-regulation mechanisms on energy intake and to

assess the effect of these self-regulation mechanisms on portion size. Separate analyses were performed for three age groups: 4 to 5 months, 6 to 11 months, and 12 to 24 months.

Results A significant negative association was found for all age groups between the number of eating occasions and average portion size *z* scores, indicating that children who eat less often during the day consume larger-than-average-portion sizes and children who eat more often during the day consume smaller-than-average portions. For infants (11 months and younger), a significant negative association was noted between energy density and average portion size *z* scores, indicating that, as the energy density of the diet goes down, infants consume larger-than-average portions and, as the energy density of the diet goes up, they consume smaller-than-average portions. Among infants 6 to 11 months, there was a significant positive relationship between portion size and the number of unique foods consumed. For toddlers, there was no association between average portion size *z* scores and energy density, suggesting that energy self-regulation mechanisms are diminished in this age group.

Conclusions Our findings confirm the presence of energy self-regulation among infants and young toddlers. These findings can be used to assure parents and caregivers that infants have an innate ability to regulate energy intake. At the same time, it is important to educate parents and caregivers about the potential for environmental cues to diminish natural hunger-driven eating behaviors, even among young toddlers. Dietetics professionals should emphasize the potential adverse effects that coercive feeding behaviors can have on children's innate ability to regulate energy intake. This includes not only admonitions to "clean your plate," but overrestriction of intake that may be motivated by concerns that children are overeating.

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Recently, several researchers have hypothesized that the increasing propensity for Americans to consume larger portions of food could be contributing to the ongoing obesity epidemic (1,2). Several studies among adults have demonstrated that larger portions can lead to increased energy intakes (3-6). Fewer studies have looked at this issue among children. In a laboratory setting, Rolls and colleagues found that portion size influenced the energy intakes of 5-year-old children, but not 3-year-olds (7). In contrast, McConahy and colleagues analyzed

data from the 1994 to 1996 and 1998 Continuing Survey of Food Intakes by Individuals (CSFII) and reported a positive association between portion size and energy intake among 1- and 2-year-olds and among preschool children (8,9).

On one hand, it seems tautological that larger portion sizes lead to higher energy intakes. However, total energy intake is influenced not only by portion size, but by the number of eating occasions in a day, the number of foods consumed, and the energy density of the foods consumed. The overall effect of portion size on energy intake may vary depending on how these other determinants of intake change as portion size changes. Studies in both controlled and free-living environments have demonstrated that infants have an innate ability to self-regulate energy intake, with intake being driven primarily by responses to hunger and satiety cues (7,10-13). Other research has shown, however, that this innate ability to self-regulate deteriorates over time as eating becomes more influenced by external cues, such as palatability, schedule/routine, and social context (7,14,15).

Total energy intake is influenced not only by portion size, but by the number of eating occasions in a day, the number of foods consumed, and the energy density of the foods consumed.

An important question to ask is: how early in children's development does the deterioration of energy self-regulation begin? To examine this issue, we analyzed data from the 2002 Feeding Infants and Toddlers Study (FITS), which collected dietary intake data on a stratified, random sample of infants and toddlers 4 to 24 months of age. The ideal analysis would assess the relationship between portion size and weight-for-height. We were unable to look at this relationship, however, because of questionable reliability of the heights reported by caregivers. As an alternative, we assessed relationships between portion size, usual energy intake, and other factors that may be used in self-regulating energy intake. These include the number of eating occasions, the total number of unique foods consumed, and energy density. We looked at the effects of portion size, number of eating occasions, number of unique foods, and energy density on energy intake and then examined how portion size varied with the other predictors of energy intake.

METHODS

Sample Design and Subjects

The 2002 FITS was sponsored by Gerber Products Company to update our knowledge of the food and nutrient intakes of infants and toddlers in the United States (16). FITS included a stratified random sample of infants between 4 and 24 months of age. The sample was drawn from Experian's New Parents Database, February to May 2002, Experian (Lincoln, NE) because it was judged to

provide the greatest coverage of infants and toddlers. Infants and toddlers were sampled in six age groups: 4 to 6 months, 7 to 8 months, 9 to 11 months, 12 to 14 months, 15 to 18 months, and 19 to 24 months. Infants 4 to 6 and 9 to 11 months of age were oversampled because these two age groups typically experience significant transitions in infant feeding patterns and practices (from liquid diets to the addition of complementary foods, and from complementary foods to the addition of table foods, respectively). Sample weights were developed to adjust for oversampling, nonresponse, and undercoverage of some subgroups of children not included in the sample frame. A detailed overview of the FITS study design and sample is available elsewhere (16,17).

In this article (and others in this supplement), we have modified the reporting categories for the two youngest age groups, relative to the age groups that have been used in previous reports of FITS data (18-25). This change was made in response to recent clarifications about the intended age groups for infants in the Dietary Reference Intakes (26-31). The life-stage groups used in the Dietary Reference Intakes define infancy as the period from birth through 12 months of age and "divide [it] into two 6-month intervals." Thus, although some text and tables in the Dietary Reference Intake reports refer to 0 to 6 months and 7 to 12 months, the actual intent is 0 through 5 months (0-5.99)—the first six months of life—and 6 through 11 months (6.0-11.99)—the second six months of life (Janice Rice Okita, PhD, RD, senior program officer, Food and Nutrition Board, Institute of Medicine, personal communication, June 7, 2005). For this reason, this article limits the youngest age group to infants 4 and 5 months old and includes infants 6 months of age in the second age group (6-11 months). The sample includes 3,022 infants, in the following age groups: 4 to 5 months (n=624), 6 to 8 months (n=708), 9 to 11 months (n=687), 12 to 14 months (n=371), 15 to 18 months (n=312), and 19 to 24 months (n=320).

Data Collection Methods

FITS data were collected by Mathematica Policy Research, Inc (Princeton, NJ). All data collection instruments and procedures were reviewed and approved by Mathematica Policy Research, Inc's institutional review board compliance officer and quality assurance system. Parents or primary caregivers of sampled infants and toddlers completed a single 24-hour dietary recall. The 24-hour recall collected information on water intake (tap water and bottled water) as well as use of dietary supplements. All recalls were completed between March and July 2002. Trained interviewers conducted the 24-hour recalls over the telephone using the Nutrition Data System for Research (version 4.03, 2001, University of Minnesota Nutrition Coordinating Center, Minneapolis). An information packet was mailed to respondents a week to 10 days prior to the interview. The packet included a detailed two-dimensional booklet for use in reporting portion sizes. The booklet was designed specifically for FITS and was pilot-tested with mothers of infants and toddlers. It included graphic depictions, drawn to scale, of common infant feeding utensils, including eight popular "sippy" cups, four different spoons, and two different bowls. Also included were circles from 1 to 8 inches in diameter, for

Milk and Formula Infant formula Milk, as a beverage Milk, on cereal Fruit/Juice Babyfood fruit Canned fruit Fresh fruit 100% juice Vegetables Babyfood vegetables Mashed potatoes Baked/boiled potatoes French fries Cooked vegetables other than potatoes Raw vegetables Breads and Grain Products Dry infant cereals Jarred infant cereals	Breads and Grain Products (continued) Ready-to-eat cereals Hot cereals Bread Rolls Crackers Pasta Rice Pancakes/waffles Meat and Other Protein Sources Babyfood meats Non-babyfood meats (all plain meat, poultry, fish) Breaded chicken products Cheese Yogurt Eggs, scrambled Peanut butter	Mixed Dishes Babyfood dinners Pizza Macaroni and cheese Soup Pasta with sauce and/or meat/cheese Other Foods Butter/margarine Candy Cookies Babyfood desserts Ice cream/ice milk Other frozen desserts/pudding Sweetened beverages Salty snacks Sugar Syrup/jam/jelly/other sweeteners
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Figure. Food groups considered in estimating portion size z scores for a national random sample of 3,022 US infants and toddlers 4 to 24 months of age.

use in reporting the size of round foods, such as cookies, pancakes, and hamburger patties, and a 5×5-inch grid for use in reporting square and rectangular foods, such as crackers and cheese, and for estimating thickness. A random subsample of 703 respondents completed a second 24-hour recall 3 to 10 days after the first recall, on a different day of the week. This second recall was used to generate estimates of usual energy and nutrient intake. Additional details about collection, processing, and quality control of 24-hour recall data are reported elsewhere (16,17).

Analytic Methods

Average portion sizes were estimated for 45 different food groups (Figure) for three age groups: infants 4 to 5 months, infants 6 to 11 months, and toddlers 12 to 24 months. In estimating average portion sizes, we followed procedures used in US Department of Agriculture reports that report population estimates of average portion sizes based on the CSFII (32,33). Details about this process are reported in another article in this supplement (34). Portions were assessed in common household measures. To compare portion sizes across children, we adapted the approach used by McConahy and colleagues (8,9) and computed, for each child, an average portion size z score. Because foods have different units of measurement, the use of z scores standardized food portions and allowed us to incorporate foods with different units of measurement into a single variable. For an individual food group, z scores express each portion size in terms of standard deviations from the sample mean. For example, let PS_j denote a child's portion size for food group j , and let SD_j denote the standard deviation of portion size. The z score for that child for food group j is defined as:

$$z \text{ score}_j = \frac{PS_j - \overline{PS}}{SD_j}$$

An overall average portion size z score for a child was then constructed by averaging the individual food group z

scores across all food groups consumed by that child, as follows:

$$z \text{ score} = \frac{\sum_{j=1}^J z \text{ score}_j}{J}$$

Z scores were computed within age group. If fewer than 25 children in an age group consumed a food group, the food group was not included in computed z scores for that age group.

Other regulation variables were defined as follows. The total number of eating occasions was defined as the total number of times a child ate during the day, excluding occasions that included only water and/or supplements. The number of unique foods was defined as the number of unique food codes included in the 24-hour recall. Energy density was computed as kilocalories/gram, including all foods, beverages, and water. The energy intake variable used in these analyses reflects the usual energy intake of each child. Estimates were computed using the second 24-hour recalls and the personal computer version of the Software of Intake Distribution Estimation (version 1.02, 2001, Iowa State University, Ames). This software adjusts for day-to-day variation in intake. Although it is generally used to adjust intake distributions, it includes a function that calculates usual intakes at the individual level. These estimates are acknowledged to be less precise than estimates of usual intake distributions (35); however, in our judgment, they are preferable to estimates based on a single 24-hour recall because they include some adjustment for day-to-day variation in intake.

We used multivariate regressions to model the relationship between the full set of regulation variables (portion size, number of eating occasions, number of unique foods, and energy density) and energy intake. Next, we modeled the relationship between the other regulation variables and portion size. Results of the latter model tell us how variations in the other regulation variables affect portion size. We used Statistical Analysis Software (version 8.2, 2001, SAS Institute, Inc, Cary, NC) in preparing data. Data were analyzed using SUDAAN (version 9.0, 2004, Research Triangle Institute, Research Triangle Park, NC), incorporating appropriate sample weights and design effects.

RESULTS

Results of the multivariate regressions for usual energy intake are summarized in Table 1. Results are consistent across age groups and indicate that each of the regulation variables is positively associated with usual energy intake. This indicates that children's energy intakes are influenced by all of the hypothesized regulation mechanisms: consuming larger-than-average portions, eating more often, eating more unique foods, and consuming a more energy-dense diet.

The results of this model are limited, however, by the fact that they reflect the impact of portion size on energy intake with all other regulation variables held constant. In this context, a positive association between portion size and energy intake is not surprising. Our second model, which examines the relationships between the other regulation variables and portion size

Table 1. Results of multivariate regressions of regulation variables as predictors of energy intake^a

Predictor	4 and 5 Months			6 to 11 Months			12 to 24 Months		
	Coefficient	SE ^b	T ratio	Coefficient	SE ^b	T ratio	Coefficient	SE ^b	T ratio
Intercept	104.99	5.45	19.26***	86.83	5.39	16.12***	51.04	5.83	8.75***
Average portion size z score	13.87	1.95	7.11***	21.12	2.35	8.97***	38.42	2.35	16.29***
No. of eating occasions	3.83	0.90	4.26***	3.62	0.62	5.85***	4.92	0.58	8.54***
No. of unique foods	2.01	0.61	3.30**	2.36	0.28	8.29***	3.25	0.30	10.90***
Energy density	5.73	1.25	4.60***	20.82	4.17	4.99***	40.12	4.76	8.43***

^aModels adjusted for age, weight-for-age, race/ethnicity, mother's employment status, mother's education, and household income.
^bSE=standard error.
**P<.01.
***P<.001.

Table 2. Results of multivariate regressions of other regulation variables as predictors of portion size^a

Predictor	4 and 5 Months			6 to 11 Months			12 to 24 Months		
	Coefficient	SE ^b	T ratio	Coefficient	SE ^b	T ratio	Coefficient	SE ^b	T ratio
Intercept	0.21	0.27	0.75	-0.45	0.12	-3.65***	-0.32	0.15	-2.18*
No. of eating occasions	-0.13	0.02	-6.02***	-0.07	0.01	-6.54***	-0.04	0.01	-3.71***
No. of unique foods	0.0	0.02	-0.13	0.02	0.01	2.58**	-0.01	0.01	-1.92
Energy density	-0.41	0.05	-7.68***	-0.26	0.07	-3.88***	0.16	0.10	1.53

^aModels adjusted for age, weight-for-age, race/ethnicity, mother's employment status, mother's education, and household income.
^bSE=standard error.
*P<.05.
**P<.01.
***P<.001.

provides a better understanding of the potential impact of portion size on energy intake. Results, summarized in Table 2, reveal a significant negative association, for all age groups, between the number of eating occasions and average portion size z scores. This indicates that, other regulation variables held constant, children who eat less often during the day consume larger-than-average-portion sizes and children who eat more often during the day consume smaller-than-average portions. Results for the other regulation variables vary across age groups. For both groups of infants, a significant negative association is noted between energy density and average portion size z scores. This indicates that, as the energy density of the diet goes down, infants consume larger-than-average portions and, as the energy density of the diet goes up, they consume smaller-than-average portions. Among infants 4 and 5 months old, there is no relationship between the number of unique foods and average portion size z scores; among infants 6 through 11 months old, there is a significant positive relationship between these two variables. The lack of an association among the youngest infants probably reflects the fact that the diets consumed by these infants are very homogeneous, relative to other age groups, and largely milk-based (19). The positive association between the number of unique foods and average portion size z scores for infants 6 through 11 months old indicates that infants in this

age group who are consuming a more varied diet are also consuming larger-than-average portions. For toddlers, there is no association between average portion size z scores and either the number of unique foods consumed or energy density.

DISCUSSION

Our findings indicate that the energy intakes of infants and toddlers are influenced by their portion sizes, the number of times they eat throughout the day, the number of unique foods consumed in a day, and the energy density of the foods consumed. These results are consistent with findings reported by McConahy and colleagues for preschool children, but contradictory to their results for 1-year-olds (8,9). In this younger age group, McConahy and colleagues reported a positive association between portion size and energy intake, but found no association between energy intake and either the number of eating occasions or number of unique foods (8). Our analysis of interactions between portion size and the other regulation variables indicates that infants and toddlers compensate for variation in the number of eating occasions by adjusting their portion sizes. This is consistent with findings from previous research in both controlled and free-living environments (10,12). In addition, the negative association between energy density and average portion size z scores among infants indicates that infants com-

pensate for changes in energy density by adjusting the amount of food they consume. This is consistent with research that has demonstrated that infants have an innate ability to adjust food intake in response to changes in the energy content of food (11,36). The lack of a relationship between energy density and portion size among toddlers suggests a diminished responsiveness to changes in energy density. Birch and colleagues report that young children's ability to adjust intake in response to alterations in energy density can be readily disrupted by the imposition of controlling child-feeding practices that attempt to regulate what and how much children eat (37).

It is important to educate parents and caregivers about the potential for environmental cues to diminish natural hunger-driven eating behaviors, even among young toddlers.

While our findings provide evidence of energy self-regulation among young infants and toddlers, they do not tell us how successful these compensatory mechanisms are in keeping infants, and especially toddlers, in energy balance. There is evidence that by the time children are 3 or 4 years old, eating may be less controlled by natural self-regulation than by responses to a variety of environmental influences (37). It is not clear how early interference with natural self-regulation may start. Several studies have suggested that bottle feeding may promote overconsumption of energy because caregivers using this feeding method may be less responsive to infants' cues about hunger and satiety than breastfeeding mothers (38,39). Tavares and colleagues found that mothers who breastfed their infants in early infancy and who breastfed for longer periods of time reported less restrictive child feeding practices at 1 year (40). Future research should assess the relationships between energy intake, self-regulation mechanisms, and the weight status of infants and toddlers.

LIMITATIONS

This study has some limitations that should be acknowledged. First, all of our data were self-reported. Caregivers may have over- or underreported intakes. There is reason to believe that overreporting was more common than underreporting (18). However, mean energy intakes of FITS toddlers are consistent with mean energy intakes reported for 1-year-olds in CSFII 1994 to 1996 and 1998 (41) and in the Third National Health and Nutrition Examination Survey (42) and the portion sizes reported in FITS are consistent with the portion sizes reported in CSFII 1994 to 1996 (8,34). Thus, if overreporting is present, it appears to be comparable to that observed in national nutrition monitoring surveys. Second, analyses are based on intake of foods during a single 24-hour period rather than "usual" food intake. Methods for estimating usual food intake are limited and cannot be ap-

plied to detailed food groups. Moreover, there is some evidence to suggest that there is less day-to-day variation in dietary intake among infants and toddlers than among older children and adults (43).

CONCLUSIONS

Our findings confirm the presence of energy self-regulation among infants and young toddlers. These findings can be used to assure parents and caregivers that infants have an innate ability to regulate energy intake. At the same time, it is important to educate parents and caregivers about the potential for environmental cues to diminish natural hunger-driven eating behaviors, even among young toddlers. Dietetics professionals should emphasize the potential adverse effects that coercive feeding behaviors can have on children's innate ability to regulate energy intake. This includes not only admonitions to "clean your plate," but overrestriction of intake that may be motivated by concerns that children are overeating (14). Satter summed up the situation quite well when she said: "Effective feeding demands a division of responsibility: The parent is responsible for what the child is offered to eat; the child is responsible for *how much* and even *whether* to eat" (44).

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