THE VARIABILITY OF YOUNG CHILDREN'S ENERGY INTAKE

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Abstract *Background.* Research conducted in the 1930s showed that, given nutritious choices, children can select an adequate diet without adult supervision. Paradoxically, children grew well and were healthy despite patterns of intake at individual meals that were unpredictable and highly variable.

Methods. To investigate in more detail the energy intake of young children, we measured 24-hour food intake for 15 children, from two to five years of age, on six days. For each of the six days of the study, coefficients of variation were calculated for each child for each of the six meals and snacks (breakfast, lunch, dinner, and morning, afternoon, and evening snacks) and for total daily energy intake.

Results. The children's intake at individual meals was highly variable, but total daily energy intake was relatively constant for each child. The mean coefficient of variation for each child's energy intake at individual meals was 33.6 percent; in contrast, the mean coefficient of variation for each child's total daily energy intake was 10.4 percent. In most cases, high energy intake at one meal was followed by low energy intake at the next meal, or vice versa.

Conclusions. Although children's food consumption is highly variable from meal to meal, daily energy intake is relatively constant, because children adjust their energy intake at successive meals. (N Engl J Med 1991; 324: 232-5.)

THE maintenance of a positive energy balance is critical in sustaining growth and health in children. In pioneering research conducted 60 years ago, Clara Davis studied the intake patterns of a group of infants on a pediatric ward who selected their own diets for several months.[1,2] Her findings revealed a paradox. On the one hand, in the absence of adult attempts to control the infants' food intake, they grew well and were healthy, leading Davis to suggest "the existence of some innate, automatic mechanism for its accomplishment." On the other hand, the children's mealtime patterns revealed that "tastes changed unpredictably . . . , refusing as we say 'to stay put.' . . . Meals were . . . a dietitian's nightmare."[2] Davis' observations are consistent with parental reports that young children's eating behavior is erratic: they eat "like a bird" on one occasion and "like a horse" on another, and foods avidly consumed one day are rejected the next.

Subsequent research has demonstrated that infants and young children can modify their intake in response to the energy content of the diet.[3-6] If young children are fed fixed volumes of a first course that is either high or low in energy content and are then given the opportunity to consume what they wish from an array of palatable foods, their energy intake is greater after the low-energy than after the high-energy first course.[4-6] Whether children's energy intake at one meal influences their intake at subsequent meals is not known, however.

We hypothesized that the apparent contradiction in the findings reported by Davis could be resolved by an examination of the variability of energy intake both at mealtimes and over a 24-hour period. We focused on total daily energy intake because it is an accepted and widely used measure and because research on patterns of intake among free-living adults has suggested that systematic patterns in intake might emerge in this period.[7] We undertook a study designed to investigate the meal-to-meal and day-to-day variability in children's energy intake, thus providing information about the precision of energy-intake regulation and about the period over which regulation occurs.

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Methods

The study subjects were 15 normal preschool children, 7 boys and 8 girls, ranging in age from 26 to 62 months. All the children were attending a day-care center that served middle-income families. Children with food allergies or any chronic health problems and those who were below the 10th or above the 90th percentile for weight or height were excluded. The protocol was approved by the University of Illinois Institutional Review Board. Informed consent was obtained from the parents of each child before the study began.

Complete 24-hour dietary information was obtained for each child for each Tuesday and Wednesday during three consecutive weeks. We chose the same two days each week because the children's schedules on those days were similar each week. During this period, the children ate in their usual home and day-care settings. They were offered the foods in menu 1 on Tuesday of each week, and the foods in menu 2 on Wednesday of each week. Meals were served at standard scheduled times; although the children had no control over when the meals were presented, they were free to consume what they wished at a particular meal. Foods providing approximately 11,300 kJ (2700 kcal) were offered each day to ensure that the children's intake was not limited by the availability of food. The estimated daily energy allowance for children from two to five years old is about 5860 kJ (1400 kcal).[8] The foods served and the macronutrient composition of the menus are shown in Table 1.

The children's food intake was measured by weighing every food both before and after all six meals (breakfast, morning snack, lunch, afternoon snack, dinner, and evening snack) on each of the six study days. The first four meals each day were consumed at the day-care center, under the supervision of trained observers. Dinner and the evening snack were consumed at home. Foods for these two meals were prepared at the center, each food item was weighed in a separate container, and the foods were taken home in an insulated food container. Detailed instructions were given to the parents to minimize errors. The children ate directly from the containers, the uneaten portions were resealed in the containers, and the insulated food container, together with its contents, was returned to the research staff at the day-care center for weighing the following morning. Parents were carefully instructed not to allow other family members to consume the food and were trained to report spills and any departures from the prescribed procedures. We did not supply meals for the other members of the household, but the participating children typically ate with the family at their scheduled mealtime. The energy content and nutrient composition of the foods offered were calculated with use of the University of Minnesota Nutrition Database and Nutrient Calculation System.

Statistical Analysis

The coefficient of variation (CV) is defined as the standard deviation divided by the mean. The CV provided an index of the day-to-day variability in energy intake for each child at individual meals, as well as for total energy intake. Calculation of the CVs made it possible to compare the variability of measures with different mean values; for example, we could compare the variability of energy intake at individual meals to the variability of energy intake over a 24-hour period. To obtain a measure of the variability of intake at individual meals for the group of 15 children, the CVs for each child were averaged for each meal. These six composite CVs (one for each meal) were then averaged for all the meals to obtain one value for the variability of intake at each of the six meals. To obtain a composite CV for total daily energy intake, the 15 children's CVs for total daily energy intake were averaged. CVs for total energy intake were also calculated for five additional 24-hour periods, each of which included parts of two calendar days and an overnight fast. The first period began with the morning snack on day 1 and ended with breakfast on day 2, and the fifth period began with the evening snack on day 1 and ended with dinner on day 2. Correlations between energy intake at a given meal and intake at the next meal (for example, intake at breakfast and morning snack, or intake at morning snack and lunch) were calculated for each child. Negative correlations between energy intake at one meal and intake at the next were obtained when high-energy meals followed low-energy meals, or vice versa. A consistent pattern of negative correlation reflected compensation in energy intake at successive meals. For each child, the number of negative correlations obtained for two successive meals (ranging from 0 to 5) provided an index of meal-to-meal compensation in energy intake. The correlation between this compensation index and the CV for total energy intake was calculated for each child.

Table 1. Menus Served to Children on Tuesday (Day 1) and Wednesday (Day 2) of Each Week, Including Macronutrient Content.

Meal	Day 1	Day 2
Breakfast	Waffles with margarine and syrup, orange juice, milk (2% fat)	Cereal and banana, orange juice, milk (2% fat)
Morning snack	Bagel with cream cheese, apple juice	Graham crackers with cream cheese, apple juice
Lunch	Soup, crackers and cheese, broccoli florets, banana, milk (2% fat)	Ham-and-cheese biscuit, corn, applesauce, milk (2% fat)
Afternoon snack	Cookies, milk (2% fat)	Cookies, milk (2% fat)
Dinner	Peanut-butter-and-jelly sandwich, cottage cheese (2% fat), carrot sticks, mixed vegetables, apple, pudding, milk (2% fat)	Macaroni and cheese, peas, grapes, nectarine, roll and margarine, brownie, milk (2% fat)
Evening snack	Corn chips, graham crackers, apple juice	Potato chips, graham crackers, apple juice
Variable		
Total energy available (kcal)*	2632	2785
Energy from protein (%)	14.5	12.1
Energy from carbohydrate (%)	57.8	57.7
Energy from fat (%)	27.8	30.1

*To convert kilocalories to kilojoules, multiply by 4.18.

Results

Descriptive information on the children's total daily energy intake is shown in Figure 1, which presents the mean total daily energy intake for the six study days for each child. Total daily energy intake for the group ranged from approximately 4600 to 7530 kJ (1100 to 1800 kcal) per day. The correlation between total daily energy intake and body weight was 0.76. As Figure 1 shows, there were large individual differences in total daily energy intake.

Variability in Energy Intake within Subjects

Figure 2 shows the CVs for energy intake at each of the six meals and snacks and for total daily energy intake for each of the 15 children (within-subject CVs). In contrast to the large CVs for each of the six meals and snacks, the CV for total daily energy intake is relatively small. This pattern is clear in the mean within-subject CVs for individual meals; the CVs were 31 percent for breakfast, 30 percent for morning snack, 31 percent for lunch, 44 percent for afternoon snack, 30 percent for dinner, and 35 percent for evening snack. In contrast, the mean within-subject CV for total daily energy intake was 10.4 percent.

Within the constraint of fixed mealtimes, the children could modulate their total daily energy intake only by varying the amount of energy they consumed at individual meals. Adjustments in energy intake at successive meals could produce the pattern we observed: small CVs for total daily intake and large CVs for the individual meals (Fig. 2). As described in Methods, correlations between energy intake at one meal and intake at the next meal were used to investigate the possibility of meal-to-meal compensation in energy intake. A preponderance of negative correlations was noted: of the 75 correlations calculated (5 correlations for each of 15 children), 48 were nega-

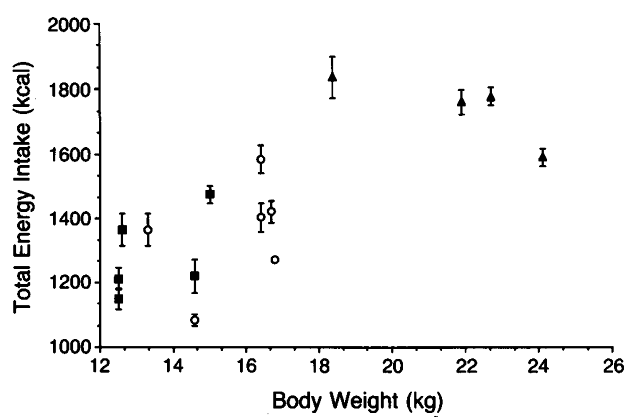

Figure 1. Body Weight and Mean Total Daily Energy Intake of 15 Children from Two to Five Years of Age.

Solid squares represent two-year-olds, open circles three-year-olds, and solid triangles four-year-olds (and one five-year-old). The I bars indicate the standard error. To convert kilocalories to kilojoules, multiply by 4.18. All values are approximate.

tive, providing evidence of compensation in energy intake from one meal to the next.

Individual Differences in Patterns of Intake

The within-subject CVs for total daily energy intake were used in conjunction with the meal-to-meal correlations just described to examine the relation between a child's CV for total daily energy intake and the evidence of meal-to-meal compensation in energy intake. The relation between the number of negative meal-to-meal correlations and the child's CV for total energy intake was significant ($r = -0.51$, $P<0.05$). The children who had the smallest CVs for total daily energy intake had the strongest evidence of meal-to-meal compensation in energy intake.

For all 15 children, the CVs for total daily energy intake were smaller than the CVs for mealtime intake, but clear differences existed among individual children's patterns of mealtime energy intake. Figure 3 shows the patterns of intake for three children for each meal and snack on the six study days. The data shown are those for the children with the lowest CV (2.5 percent), the highest CV (17.5 percent), and the median CV (10.9 percent) for total daily energy intake. In addition to individual differences in the variability of energy intake, the children's intake profiles were also distinctive. These profiles are probably influenced by the preferences of the individual children for the foods offered. For example, the large and consistent peak for Subject 15 at dinner on Wednesday of each week may reflect that child's enthusiasm for macaroni and cheese.

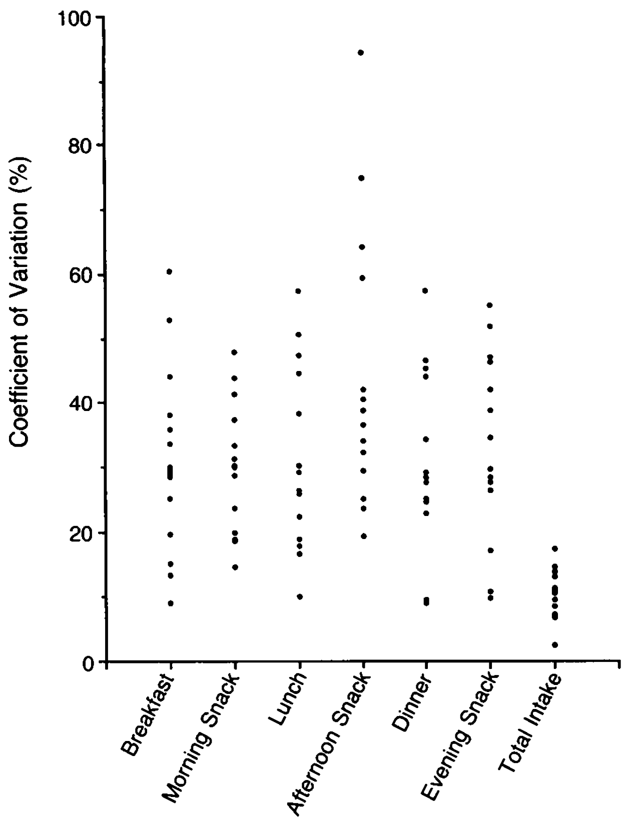

Figure 2. Coefficients of Variation for Total Energy Intake and for Intake at the Six Meals and Snacks for Individual Children (within-Subject Variation).

Each point represents the mean value for a single child for six days, except where the values for two children coincide and one data point is shown.

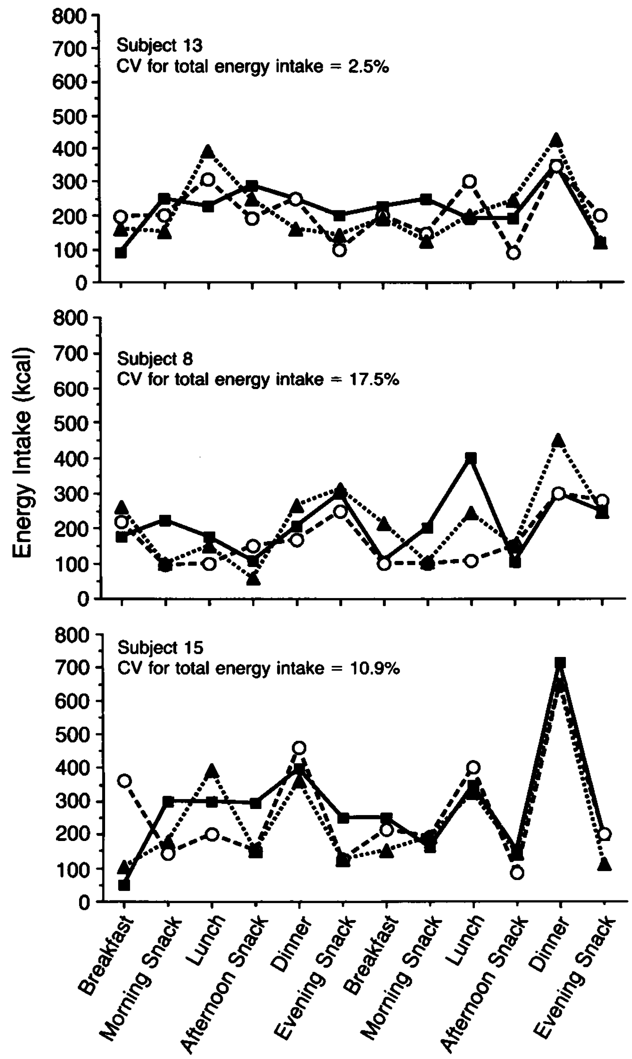

Figure 3. Energy Intake at Mealtimes for Three Children with Low, High, and Median Coefficients of Variation for Total Daily Energy Intake.

The solid squares indicate values for the first week of the study, the open circles values for the second week, and the solid triangles values for the third week. To convert kilocalories to kilojoules, multiply by 4.18.

Period of Intake Regulation

We also investigated the variation in total energy intake over different 24-hour periods to determine whether there was something unique about the calendar day for the control of energy intake. The within-subject CVs for total daily energy intake reported above were calculated with use of the conventional 24-hour period (from morning to evening of a calendar day). We also used five additional 24-hour periods, all of which included an overnight fast. When calculated for the five other 24-hour periods, which included parts of two calendar days, the mean within-subject values were comparable to those for the calendar day (10.4 percent) — 10.9, 12.3, 11.5, 12.4, and 11.4 percent. The pattern of small within-subject CVs for total energy in comparison with the CVs for individual meals therefore was evident whether the data on intake were analyzed according to calendar day or according to 24-hour periods that included parts of two days and an overnight fast.

Discussion

For each child, energy intake at a given mealtime was highly variable. On two occasions when the same menu was offered, a child might consume a breakfast consisting of food providing 420 kJ (100 kcal); on another, he or she might consume foods providing 1470 kJ (350 kcal). In comparison with the variability of intake at mealtimes, the variability of total daily energy intake was low. This general pattern emerged consistently among the 15 children, despite individual differences in the degree of variability and the absolute level of energy intake. These findings are reminiscent of the contradictory picture presented by Davis' findings: children's intake at individual meals was unpredictable and highly variable, yet the children grew well and were healthy, suggesting the existence of some orderly control mechanism. Order appeared when a different level of analysis was adopted, and our results indicate that the resolution of the paradox may be found in the way energy intake is regulated over a longer period of time. Although each child's intake at individual meals was erratic, the existence of an orderly mechanism was evident in the relatively small CVs for total energy intake. The children's intake at individual meals was not independent, and there was evidence that high energy intake at one meal was often compensated for by low energy intake at the next, and vice versa.

Individual differences in the children's CVs for total daily energy intake were systematically related to individual differences in the patterns of meal-to-meal correlations. This pattern provides support for the view that the relatively small CVs for total energy intake were due in part to compensation in energy intake at successive meals. Simple correlations between one meal and the next provide a conservative estimate of energy compensation at successive meals, however, because they do not reflect compensation that may be occurring at meals eaten after the next meal; the meal-to-meal correlations we used fail, for example, to capture compensation at lunch for high or low energy intake at breakfast. Although some children showed little evidence of energy compensation at successive meals, all had CVs for individual mealtimes that were larger than their CVs for total daily energy intake. This pattern may have resulted from compensation at meals after the next meal for high or low energy intake earlier in the day.

Previous research demonstrated that children can respond to the energy density of foods in regulating their intake at single meals.[4-6] Our data provide evidence for the behavioral regulation of food intake by young children over 24-hour periods. In an earlier study by Harries et al.,[9] the reported CVs for total daily energy intake were 18 percent for preschool children and ranged between 15 and 30 percent for young adults. Our values are similar but somewhat lower, perhaps because we were able to control the foods served to the children. However, Harries et al. did not obtain estimates of the variability of energy intake at individual meals that could be compared with their estimates of the variability of total daily energy intake.

In addition to providing basic information on the regulation of energy intake, these results have important practical implications. Many parents assume that their young children cannot adequately regulate their food intake, and parental observations of the erratic eating patterns of their children provide support for this belief. In response, parents often adopt coercive strategies in an attempt to ensure that the child consumes a nutritionally adequate diet. These strategies can include the use of threats and bribes and of rewards or punishment contingent on eating behavior. Previous research indicates that such control strategies are counterproductive[10,11]; parents' attempts to control their child's eating were reported more often by obese adults than by adults of normal weight.[12] At least with respect to the regulation of energy intake, the results of our study suggest that coercive feeding strategies may also be unnecessary. As revealed by Clara Davis 60 years ago, the successful feeding of children is best accomplished by providing them with a variety of healthful foods and allowing them to eat what they wish.

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