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Development of Eating Behaviors Among Children and Adolescents

Leann L. Birch, PhD, and Jennifer O. Fisher, PhD

ABSTRACT. The prevalence of obesity among children is high and is increasing. We know that obesity runs in families, with children of obese parents at greater risk of developing obesity than children of thin parents. Research on genetic factors in obesity has provided us with estimates of the proportion of the variance in a population accounted for by genetic factors. However, this research does not provide information regarding individual development. To design effective preventive interventions, research is needed to delineate how genetics and environmental factors interact in the etiology of childhood obesity. Addressing this question is especially challenging because parents provide both genes and environment for children.

An enormous amount of learning about food and eating occurs during the transition from the exclusive milk diet of infancy to the omnivore's diet consumed by early childhood. This early learning is constrained by children's genetic predispositions, which include the unlearned preference for sweet tastes, salty tastes, and the rejection of sour and bitter tastes. Children also are predisposed to reject new foods and to learn associations between foods' flavors and the postingestive consequences of eating. Evidence suggests that children can respond to the energy density of the diet and that although intake at individual meals is erratic, 24-hour energy intake is relatively well regulated. There are individual differences in the regulation of energy intake as early as the preschool period. These individual differences in self-regulation are associated with differences in child-feeding practices and with children's adiposity. This suggests that child-feeding practices have the potential to affect children's energy balance via altering patterns of intake. Initial evidence indicates that imposition of stringent parental controls can potentiate preferences for high-fat, energy-dense foods, limit children's acceptance of a variety of foods, and disrupt children's regulation of energy intake by altering children's responsiveness to internal cues of hunger and satiety. This can occur when well-intended but concerned parents assume that children need help in determining what, when, and how much to eat and when parents impose child-feeding practices that provide children with few opportunities for self-control. Implications of these findings for preventive interventions are discussed. *Pediatrics* 1998;101: 539–549; *children, food, eating, obesity, dieting, parenting.*

ABBREVIATION. BMI, body mass index.

This article addresses behavioral factors that influence food preferences, food intake, and energy regulation in children. Currently, the prevalence of childhood overweight is high and has increased dramatically since the 1970s.[1,2] This increased prevalence is of concern because overweight children are at increased risk for social stigmatization, adult obesity, and chronic disease. Obesity shows familial aggregation; the risk of obesity among children of two obese parents is much higher than for children in families in which neither parent is obese.[3] Familial aggregation has focused research attention on genetic factors in obesity,[4] but the rapid secular increase in the prevalence of obesity cannot be attributable to genetic factors. The interaction of genes and environment influences phenotypes for intake and expenditure and suggests that a renewed focus on the family environment may provide information about behavioral factors that contribute to familial aggregation of adiposity.

Between 30% and 50% of the variance in adiposity within a population is attributable to genetic differences.[5] However, these heritability estimates describe populations, not individuals, and do not provide information about the ways genetics and environment interact during development to produce childhood obesity. In the case of childhood obesity, the question is especially complex because 1) genes and environments also tend to be correlated—parents typically provide children with both genetics and environment; and 2) genetic factors can include behavioral predispositions that affect food intake and expenditure.[4] A more complete understanding of what may characterize obesigenic environments

From the Department of Human Development and Family Studies and the Graduate Program in Nutrition, Pennsylvania State University, University Park, Pennsylvania.
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for children is needed, and this review of behavioral factors that influence intake and expenditure indicates ways the family environment can interact with genetic predispositions to produce patterns of food preferences, food consumption, and physical activity that can promote childhood obesity in susceptible individuals.

Obesity results when intake exceeds expenditure, and both sides of the energy-balance equation must be considered in concert in research on the etiology of childhood obesity. Unfortunately, scant research has adopted a conjoint focus on intake and expenditure; thus, we have little knowledge about how children's food intake and physical activity may interact to influence energy balance. Our knowledge also is limited by the lack of precision of the national databases on children's energy intake and the absence of a national database on children's physical activity. Finally, among adults and children, diets high in fat and low in complex carbohydrates are associated with greater adiposity. However, despite repeated recommendations to reduce fat intake, adults' and children's diets are still too high in fat and too low in complex carbohydrates. Our analysis of behavioral factors that influence children's energy intake focuses on research on factors that influence the development of food preferences and the controls of food intake in children. This research will reveal why it is difficult to reduce the intake of energy-dense foods, especially dietary fat intake, and increase complex carbohydrate intake. These findings indicate that attempts to restrict and control children's eating and weight to prevent obesity may be iatrogenic, producing the very problem they are intended to avoid—fostering the development of problems of energy balance. This research also suggests some strategies that can be incorporated into the design of preventive interventions.

DIET COMPOSITION: HIGH-FAT DIETS, COMPLEX CARBOHYDRATES, AND OBESITY

Several investigators have recently reported links among parental adiposity, parental fat intake, and children's adiposity and fat intake,[6–8] which suggest that familial patterns of adiposity may be partially mediated by familial similarities in diet composition. Factors that contribute to parent–child similarities in diet composition, including availability, accessibility, and exposure effects on children's food preferences, are discussed below.

In one of the few prospective longitudinal studies of childhood obesity that included measures of physical activity, dietary intake, and familial predisposition for obesity in children, Klesges and colleagues[9] obtained data over a 3-year period. They categorized factors as modifiable and nonmodifiable and noted that the largely nonmodifiable factors of initial body mass index (BMI), sex, and number of obese parents accounted for 9% of the variance in BMI change. Dietary intake and physical activity accounted for an additional 13%. High levels of dietary fat were associated with greater adiposity and greater gain. Although Klesges' research is exemplary because it is one of the few prospective studies to incorporate both measures of energy intake and expenditure, his parsing of factors into modifiable environmental factors (diet and physical activity) and nonmodifiable genetic factors (number of obese parents) is conceptually problematic. As Leibel[10] points out in his commentary on the article by Klesges and colleagues, the genetic predispositions for obesity may well be heritable behavioral predispositions on both the intake and expenditure sides, perhaps a predisposition for high-fat diets and for low levels of physical activity. Parents provide these genetic predispositions, but they also provide the environment in which these predispositions are expressed, and the evidence indicates that eating environments in families in which parents are obese may differ in systematic ways from families in which neither parent is obese. We return to this point in subsequent sections.

Experimental work as well as epidemiologic evidence in humans and rats has implicated the percentage of energy from fat in the development and maintenance of obesity.[11,12] Because fat is very energy-dense relative to fat and carbohydrate, diets higher in fat typically are higher in total energy and smaller in volume, an important satiety cue. In addition, high-fat foods are often very palatable, which also leads to overconsumption. Several investigators have also reported that fat is less satiating than protein or carbohydrate[13–15] and that people are less likely to adjust subsequent intake to compensate for the energy in a high-fat meal,[16] thereby leading to consumption of excessive amounts of energy. Dietary fat also is stored more efficiently than ingested carbohydrate or protein. Finally, perhaps because people can store large amounts of fat, oxidation of dietary fat does not increase as fat intake increases, as is the case with protein and carbohydrate. The control of fat intake appears to be critical in regulation of energy intake and body weight.[17,18]

In addition to its direct implication as a causal agent for development of obesity, dietary fat intake also may displace more micronutrient-dense, fibrous, carbohydrate-containing foods in the diet. In the diets of adults and children in the United States, intakes of fat and carbohydrate are negatively correlated; diets that are high in fruits and vegetables and complex carbohydrates tend to be low in fat and vice versa.[19] This observed relationship has led to public health messages that emphasize increasing the intake of fruits, vegetables, whole grains, and low-fat dairy products instead of focusing exclusively on messages to decrease dietary fat intake. Because of the potential negative effects of restriction on children's preferences and intake, these messages should continue to be central in campaigns to prevent childhood obesity (eg, the "five-a-day" campaign), given that the contemporary dietary patterns of children are most similar to those of adults on high-fat diets. Findings from the Bogalusa sample of 10-year-olds[20] underscore the importance of emphasizing complex carbohydrates; children with the lowest fat intakes had higher carbohydrate intakes than those with higher fat intakes, but the lower fat intakes were associated with higher intakes of simple sugars, not complex

carbohydrates. Fruit and vegetable consumption did not differ across the groups and was uniformly low.

Current dietary recommendations[21–25] advocate reducing fat intake and increasing consumption of complex carbohydrate and fiber-containing foods including vegetables and fruits. According to 1990 to 1991 data,[24] only ~15% of 6- to 19-year-olds have diets with the recommended levels of 30% of energy from fat, consistent with the American Academy of Pediatrics Guidelines.[21] Approximately 15% of children have diets in which >40% of energy is from fat. Additionally, children's consumption of fruits and vegetables is well below current recommendations. In a study of 1797 second- and fifth-grade children, 40% of the children ate no vegetables on the days studied, and 36% ate at least four different types of snack foods.[26] Continuing Survey of Food Intakes by Individuals data from 1989 to 1991 revealed that only one in five children and adolescents consumed five or more servings of fruits and vegetables per day and that 25% of the vegetables were French fries.[27] Why do children readily consume foods high in fat and sugar and so few fruits and vegetables? A look at the factors that influence children's food preferences and food intake may provide some answers.

FOOD PREFERENCES AS DETERMINANTS OF CHILDREN'S INTAKE

Given children's very low levels of fruit and vegetable intake and the negative association between fruit and vegetable intake and dietary fat intake, increasing fruit and vegetable consumption should improve the quality of children's diets. In recent research, Baranowski and colleagues[28,29] examined the influence of a variety of psychological, social, and demographic factors on children's consumption of fruits and vegetables. In these two studies of school children, they noted that fruit and vegetable preferences were the only significant predictors of fruit and vegetable consumption, and they concluded that interventions that alter children's food preferences may be more effective than other strategies pursued to date. However, to do this we need information about the factors that influence the formation of children's food preferences. See reviews of this literature by Birch and Fisher.[30,31]

As we examine the evidence on children's food preferences and dietary selections, we see that achieving the objectives of dietary guidelines to reduce fat intake and increase complex carbohydrate intake may constitute a formidable challenge: "The most familiar and preferred foods in childhood tend to combine these two principal ingredients: sugar and fat."[32] Because children eat what they like and leave the rest, food preferences are especially important determinants of the food intake of young children.[6,28,33–35] The choices children make are important in considering the overall nutritional quality of their diets. In a recent study by Fisher and Birch,[6] children's 24-hour dietary intake was measured by using weighed food intake data on six separate occasions. Although the same diet consisting of ~33% of energy from fat was served to all children, the food choices the children made resulted in a wide range of observed dietary fat intakes, ranging from 25% to 42% of energy, from well below to well above the recommendations of the American Academy of Pediatrics.[21] Offering an array of foods that constituted a healthful diet (moderate in percentage of energy from fat) was not sufficient to ensure intake of that diet; children's food preferences were determinants of their consumption patterns. The children's preferences for the high-fat foods predicted their fat consumption, and these preferences and consumption patterns were related to their parents' adiposity. Because children's food preferences are important determinants of intake, understanding the factors that shape food preferences in early development is critical in identifying those aspects of family environments that are potentially obesigenic for susceptible individuals.

EARLY EXPERIENCE, LEARNING, AND CHILDREN'S FOOD PREFERENCES

One of the first choices that parents make that shapes a child's experience with food and flavors is the choice to breastfeed or formula-feed. The perception of flavors in milk also is one of the human infant's earliest sensory experiences, and there is support for the idea that this early experience with flavors has an effect on milk intake and on later food acceptance.[36] Mennella and Beauchamp[37,38] have reported that flavors in breast milk influence infants' consumption; breast milk flavored with garlic or vanilla increased the time attached to the maternal nipple relative to breast milk produced on a bland diet. Although Mennella and Beauchamp's research has not focused on individual differences in infants' responsiveness to flavors in milk, a potentially fruitful area for research would explore whether infants who differ in nutritive sucking style, which Agras and colleagues[39] have related to infant adiposity, also differ in their response to flavors in milk or in the extent to which flavors modulate their ingestion of milk.

Galef and Henderson's[40,41] research with rat pups has demonstrated that early experience with the flavors of the maternal diet can affect subsequent preference for and intake of solid foods. Because of repeated early experience with flavors of the maternal diet present in the mothers' milk, rat pups learn to prefer their mothers' diet. Certainly the early sensory experience of breastfed infants is radically different from that of the formula-fed infant, but we know nothing about how this affects subsequent dietary patterns. Formula-fed infants have experience with only a single flavor, whereas breastfed infants are exposed to a variety of flavors from the maternal diet that are transmitted to the milk. The long-term effects of breastfeeding versus formula-feeding remain unexplored, but very limited evidence suggests that the varied flavor experience of breastfed infants can facilitate acceptance of solid foods during the weanling period,[36] with breastfed infants showing greater initial acceptance of new foods than formula-fed infants. This finding is consistent with those showing that early experience with a variety of flavors leads to more ready acceptance of new foods later.[42] Whether infants differing in familial risk for adipos-

ity may differ in their early responsiveness to flavors or in the transition to solid foods has not been explored, but such research could yield valuable information about the developmental history of gene–environment interactions.

Thus, infant dietary experience is shaped by infant-feeding decisions and dietary patterns of the mother, and it provides the basis for food acceptance and patterns of intake in infancy. During the first years of life, the infant transitions from an exclusive milk diet to a variety of foods. This transition from univore to omnivore is shaped by the infant's innate preference for sweet and salty tastes, by the rejection of sour and bitter tastes,[43] and by the omnivore's predisposition to associate food flavors with the contexts and consequences of eating.[44] Infants and children also are predisposed to be neophobic and reject new foods. With the exception of sweet and salty foods, acceptance of new foods does not occur instantly; however, after repeated opportunities to consume new foods, liking for new food generally increases, producing increased intake, although 5 to 10 exposures often are required.[36,45–47] These findings emphasize the central importance of early experience with foods and food acceptance; children come to like and eat what is familiar. What is familiar is what is present in the environment. There are some data in support of similar dietary patterns between parents and children. Oliveria and colleagues[48] reported that parental eating habits had an effect on the nutrient intakes of young children in that children whose parents ate diets high in saturated fat also ate diets high in saturated fats. Parents tend to have foods in the home that they like and eat, and with repeated opportunities to eat these foods, young children include many of them in their diets.

The food environment the parent provides shapes children's preferences and food acceptance patterns, which in turn are linked to children's adiposity;[6,8,48] we argue that these effects are mediated primarily by the patterns of preference that children have developed as a result of these exposure patterns. The early exposure that children have to fruits and vegetables and to foods high in energy, sugar, and fat may play an important role in establishing a hierarchy of food preferences and selection. The work of Baranowski's group[49] also has confirmed that food availability and accessibility was positively related to fruit and vegetable preferences and to their consumption by school children. These authors noted that children consumed more fruits and vegetables at schools where more fruits and vegetables were served, and they concluded that the extent to which fruits and vegetables are made available and accessible to children may shape children's liking for and consumption of those foods. However, although availability and accessibility are necessary for acceptance of many foods, the physiologic consequences of eating as well as the social context also play a role.

Food Preferences: Predispositions to Prefer Energy-dense Foods

Although repeated exposure can enhance liking for a wide variety of new foods, other learning mechanisms favor development of preferences for energy-dense foods. There is no evidence that children have an innate, unlearned preference for high-fat or high-energy foods (see Birch[30] for a discussion of this point). Children are predisposed to learn to prefer energy-dense foods over energy-dilute foods by learning to associate the flavors of these foods with the positive physiologic consequences that result from eating energy-dense foods, especially when they are hungry. Although limited, the findings from research with young children[50–53] are consistent with extensive data in the literature on conditioned preferences for energy-dense foods in animals.[54]

In particular, repeated experience with foods high in energy can enhance children's preferences for those foods via associative conditioning. In this form of learning, flavors in foods become associated with satiation cues involved in digestion and absorption of high-energy foods.[52–54] These learned associations can produce flavor preferences that may mediate the relationship between children's exposure to and liking of high-energy foods. In addition, the physiologic consequences of consuming high-energy high-density foods may enhance the effects of repeated exposure on liking. The physiologic conditioning of flavor preferences for foods high in energy density may have the greatest effect on children's liking of energy-dense foods among families in which those foods are most available and accessible. To date, there has been no research exploring whether children's ability to learn preferences for foods high in fat might differ for children in obese and normal-weight families. Genetic differences could shape phenotypic differences in how readily children learn preferences for high-fat foods. Among adults, there are differences between obese and normal-weight individuals in their preferences for fat and for mixtures of sugar and fat,[55,56] and this suggests a mechanism that could be involved in the etiology of these differences.

The Social Context of Eating: Effects on Children's Preferences

For children, eating typically is a social occasion, and other eaters, including parents, other adults, peers, and siblings, as well as children's observations of others' eating behavior, influence the development of their own preferences and eating behaviors. The social context in which children's eating patterns develop becomes important because the eating behavior of people in that environment serves as a model for the developing child. Models can have powerful effects on food selection, especially when the model is similar to the observer[57,58] or is seen as particularly powerful,[59] as in the case of older peers. Findings suggest that day care could provide opportunities for expanding the availability and accessibility of foods and for fostering preferences for foods by modeling effects. Birch[57] found that when preschool children were given opportunities during meals to observe other children choosing and eating vegetables that the observing child did not like, preferences for and intake of the disliked vegetables were increased.

Modeling appears to play an important role in

establishing preferences for inherently unpalatable substances. Rozin and Schiller[60] demonstrated the powerful role of social influences in the development of preferences for chili peppers, a flavor that is aversive to animals and to many humans. Rozin and Kennel[61] reported that although a variety of established learning protocols failed to facilitate preference for chili peppers among nonhuman primates, increased preference for chili-flavored crackers resulted after the monkeys observed their keepers eating the crackers. Rozin and colleagues[60] reported a similar phenomenon among humans in Mexican families, in which the older members modeled eating chili-flavored foods for young children, which facilitated children's acceptance of hot foods.

Children's food preferences may be shaped by observing food selection patterns and eating behavior of their parents. For instance, Harper and Sanders[62] observed that toddlers put foods in their mouths more readily when they were following the example of their mothers relative to the same modeling behavior by a stranger. Especially in families in which obesity, dieting, and weight control are salient issues, children's eating may be influenced by parents' eating, dietary restraint, and disinhibition.[63] Models also may play a role in the emergence of dieting behaviors in childhood and adolescence. Pike and Rodin[64] reported that dieting daughters are likely to have dieting mothers and that parents who report dietary disinhibition and problems in controlling their own eating are likely to have daughters who show similar patterns,[65] which suggests a role for modeling in these familial patterns.

Effects of Television on Children's Food Preferences and Food Selection

Television is a pervasive purveyor of culture, providing children with a wide array of models and messages about eating that can influence children's food preferences and food selection as well as their activity patterns. However, despite the central role of television as a purveyor of American culture, surprisingly few studies have investigated the effect of television on children's food preferences, intake, and adiposity. Although there do not appear to be dramatic changes in watching television by children during the period of increased prevalence of childhood obesity, the largest share of advertisements during children's programming is for food products.[66] In 1987, in a content analysis of food advertisements that were on television during a 12-hour period, Cotugna[67] observed that 80% of advertisements showed foods with low nutritional value, including breakfast cereals high in simple sugars and snack foods high in sugar, fat, and salt. A number of investigations have revealed that children's requests for foods were related to the frequency with which children saw the foods advertised on television.[68,69] Goldberg et al[70] observed that children who were exposed to advertisements selected more sugared foods than children who had not viewed any advertisements. Thus, repeated exposure to food advertisements for particular types of foods may foster children's preferences for energy-dense, nutrient-poor foods. We know even less about how the depiction of eating, dieting, and exercise patterns may influence children's food intake and activity patterns.

Child-feeding Practices, Children's Food Preferences, and Food Selection

Parents shape their children's eating environments in a variety of ways: through the choice of an infant feeding method, by the foods they make available and accessible, by direct modeling influences, by the extent of media exposure in the home, and by way they interact with children in the eating context. Parents believe that their feeding practices can exert a major influence on children's food preferences and on developing control of children's food intake,[71] although recent research indicates that the influence is not necessarily in the ways that parents intend.[72] The pervasive messages directed at ways that nutrition can improve health and appearance have created an increasingly complex eating environment in which parents attempt to foster healthy eating behaviors in their children. For example, the messages of the dietary guidelines convey the importance of consuming certain types of foods and limiting the consumption of others.[23] The means by which parents attempt to shape children's eating toward nutritionally desirable dietary outcomes can have unintended consequences for children's eating behavior. Parents' practices may be especially controlling and may have particularly negative effects on children when there is heightened concern that the child may be at risk for obesity.[73]

Although current guidelines attempt to convey the importance of variety and moderation, these nutritional guidelines are cognitively complex. Rozin et al,[74] in a study of adults' understanding of nutritional concepts, concluded that even well-educated adults engaged in categorical thinking, ie, grouping foods as either "good" or "bad," and a monotonic mind belief that something that is harmful in large quantities (such as dietary fat) is also harmful at low levels. Nutritional messages interpreted with such categorical thinking may result in parental attempts to restrict children's intake of "bad" foods and encourage the intake of "good" foods.

Parental Control to Encourage or Limit Children's Eating

Child-feeding practices that control what and how much children eat also can affect their food preferences. Child-feeding strategies that encourage children to consume a particular food increase children's dislike for that food.[75–77] Many of the foods that parents encourage children to consume are the fruits and vegetables they would like to see consumed with greater frequency and in greater quantities. Hertzler[78] noted that parents' feedback to children about eating vegetables was associated with children's preferences for fewer vegetables.

In carrying out what one clinician described as "good food intentions," parents frequently may limit their children's consumption of "bad" but palatable foods by withholding these foods as punishment.[79,80]

In a recent study assessing parental opinions on the efficacy of using various practices to modify their children's food preferences, 40% of parents spontaneously reported the belief that restricting or forbidding the consumption of a particular food would decrease their child's preference for that food,[81] a prediction opposite research findings. Contrary to these parental beliefs, restricting children's access to foods does not produce food dislikes for the restricted food; instead, such practices enhance liking and can increase intake. Birch et al[82] found that children's preferences for foods increased after the foods were used as rewards for performing a nonfood-related task; limiting the availability of the reward food promoted children's liking of those foods. Again, these restricted foods are typically "bad" foods, those palatable foods that are high in sugar, fat, and energy and that we would like to see consumed in smaller amounts and on fewer occasions. Restricting children's access to foods actually may promote their overconsumption of those foods. Fisher and Birch[6] found that maternal restriction of children's access to snack foods was related to girls' (but not to boys') consumption of those same foods in an unrestricted setting.

Creating dietary habits that include moderation and limited consumption of dietary fat and sugar constitutes a desirable objective of child-feeding. However, the limited evidence on the effects of these practices on children's preferences suggests that restricting children's consumption of "bad" foods and encouraging consumption of "good" foods does not provide a means of achieving these dietary goals. From a developmental perspective, this type of feeding practice may send mixed messages to children, because these same forbidden foods are offered in positive social contexts such as parties, dinners out, and holiday celebrations, and are restricted in others. Finally, restricting access to some foods and encouraging consumption of others may well foster children's categorical thinking about "good" and "bad" foods. In a study that involved focus groups of kindergarten children, Murphy et al[83] concluded that children tended to indicate preference for fatty and sugary foods but that they also identified those foods as being high in fat and "not good for you." However, just to show that the implications for intervention are not simple, the work by Smith and Epstein[84] confirmed that limiting the availability of a preferred food also may enhance children's desire to obtain a less preferred food when both types are present.

Parental Control and Children's Self-regulation of Food Intake

In addition to influencing which foods children prefer and select, controlling child-feeding practices may affect children's ability to regulate energy intake and the amount of food consumed. As indicated above, a very early decision parents make is choosing whether to formula-feed or breastfeed their infant. In the United States, formula-fed infants show more rapid growth than breastfed infants, and these differences are of sufficient magnitude that some experts have suggested that different growth norms should be used for breastfed and bottle-fed infants. Fomon[85] speculates that the differences in infant growth may be attributable to differences in intake, with the greater intakes by formula-fed infants resulting from overfeeding as a result of heightened maternal control over the infant's intake. In the case of the formula-fed infant, the mother can see how much formula remains in the bottle and she may be inclined to take control of how much the infant eats, encouraging the infant to finish the bottle. In contrast, the breastfed infant may have more control over the size of the feed because this feedback is not available to the mother.

Clearly, maternal feeding practices can influence infant intake. In a series of experiments to investigate whether the energy density of formula influenced infants' intake, Fomon and colleagues varied the energy density of formulas infants were consuming and demonstrated that in the absence of maternal control, infants 6 weeks old adjusted their volume of formula intake, consuming more of energy-dilute than of concentrated formulas, so that total energy intake did not differ across the conditions.[85] Fomon's research suggests that when given the opportunity, infants are capable of being responsive to the energy density of formula and adjusting intake accordingly; however, maternal control can override the infant's regulatory ability. There is some evidence for a parallel relationship between parental control and children's ability to regulate intake during early childhood. Although many children continue to be sensitive to internal signals arising from the energy density of the diet in controlling their food intake, child-feeding practices that encourage or restrict children's consumption of foods may decrease the extent to which children use internal signals of hunger and satiety as a basis for adjusting energy intake. To investigate children's responsiveness to energy density, we have conducted research examining children's intake within individual meals by using two-course preloading protocols as well as by examining children's intake across meals by using 24-hour self-selected energy intakes.

To determine whether they could adjust intake in response to the energy density of foods within meals, we had children consume a fixed amount of a first course that varied in energy density, by manipulating fat or carbohydrate content, and looked at effects on children's self-selected food intake in a second course. We predicted that if children were responsive to the energy density of the first course, they would eat less in the self-selected second course after the high-energy than after the low-energy first course. Across a series of experiments, findings confirmed this prediction,[50–53,86,87] providing evidence that children can regulate their intake based on feedback arising from the energy content of foods just consumed. Subsequent research extended our findings to reveal that children's responsiveness to energy density can affect their food intake not only within a meal but also across a series of meals, influencing their 24-hour energy intake. Children showed adjustments in energy intake across successive meals in a manner similar to the adjustments in energy intake

observed within meals. These adjustments resulted in relatively consistent coefficients of variation for 24-hour energy intake, which averaged ~10%, compared with the much higher coefficients of variation of ~40% for energy intake at individual meals.[88,89] Children also adjusted their intake to compensate for reduced energy density of meals produced when we substituted olestra for dietary fat, indicating that at least when energy density is reduced, children are responsive to and adjust intake for the energy dilution. Whether children's ability to adjust their food intake in response to energy density is impaired when diets are very high in fat remains an unanswered question.

With respect to whether child-feeding practices can alter children's responsiveness to energy density, our initial findings revealed that children's responsiveness to energy density was diminished when adults used control strategies that focused children on external cues to encourage consumption. We explored children's ability to adjust food intake in response to differences in energy density in two different child-feeding contexts. In one condition, child-feeding practices focused on internal cues of hunger and satiety as controls of food intake. In this condition, children showed clear evidence of adjusting their intake in response to the energy-density differences in the first course. In the other condition, child-feeding practices included rewarding children for cleaning their plates and a focus on external cues to control eating, such as the amount of food remaining on the plate. In the latter condition, all evidence of responsiveness to the energy content of the foods disappeared, and children's intake was significantly increased by rewarding them for eating.[86] These findings suggested a powerful role for child-feeding practices in shaping how much children eat and the extent to which children are responsive to the energy density of the diet in controlling their food intake. Other evidence on this issue comes from observations of family meal times by Klesges et al.[90] They found that parental prompts to eat were positively associated with time spent eating and degree of overweight in children. Interestingly, in an examination of the sequencing of parental prompts to eat, Klesges and colleagues[91] observed that prompts to eat were preceded by food refusals by the child and followed by the child eating. These findings suggest that parental prompts to eat may act to oppose children's own attempts to control the amount consumed and promote consumption within a meal.

Factors Influencing Child-feeding Practices: Gender, Adiposity, and Eating Style

Although the potential of nutritional messages to promote restrictive child-feeding practices exists on a societal level, eating-related issues within families also determine parental use of controlling feeding practices. In discussing children's obesity proneness, Costanzo and Woody[73] assert that parents impose behavioral control in domains of their children's development when 1) the parents have problems regulating their own behavior, 2) the child is perceived to be at risk for developing problematic behavior, and 3) the child demonstrates a lack of self-regulatory behavior. These authors use obesity proneness as an example and contend that the use of controlling parenting styles impedes children's ability to develop self-regulatory behavior, thereby promoting the problems they attempt to avoid.

Subsequent research by Johnson and Birch[72] confirmed the links among child-feeding practices and children's responsiveness to energy density. Children's compensation for energy density in our standard two-course-meal protocol was used as a measure of individual differences in regulation of energy intake. Parents who reported using a high degree of control over what and how much their children ate had children who showed relatively little evidence of energy regulation; a high degree of parental control was associated with low self-control in children. For girls, energy regulation was related to their adiposity, with thinner girls regulating energy intake more precisely than heavier ones. In addition, for girls, but not for boys, parental control was linked to the girls' adiposity, with parents using more control with heavier girls. Parental control also was linked to the parents' dieting and weight history. Mothers who were more restrained used more control and had daughters (but not so for mothers with sons) who showed little evidence of energy regulation. These early gender differences may be precursors of later gender differences in problems of energy balance, in which the prevalence of eating problems is much higher among women. These findings are limited to middle-class white families; we have no data on whether such relationships exist among other racial, ethnic, or socioeconomic groups. One area for future research is to determine whether racial and socioeconomic differences in the prevalence of obesity in children (reported by Troiano and Flegal)[1] may be mediated in part by racial and socioeconomic differences in parenting practices.

Fisher and Birch[65] found that young children's weight for height predicted the degree to which mothers reported restricting their child's intake of snack foods. For girls, the parents' dieting and restrictive eating predicted the level of maternal restriction. The cross-sectional nature of the data cannot address the causal direction of the relationships observed, but the results suggest that controlling child-feeding practices adversely affects children's ability to self-regulate food intake and hence their adiposity, although it is possible that parents of heavier children are more controlling. We are obtaining longitudinal data on this question.

The child's eating style also may elicit parental concern and control and influence the extent to which the parent sees the child as at risk for obesity and eating problems. Stunkard and Kaplan[92] reported that the obese ate at a faster rate than normal individuals. Comparisons of obese and normal children have yielded similar results. Drabman et al[93] reported that obese preschoolers ate at a faster rate, taking more bites, and chewing each bite fewer times. Marston and colleagues[94] reported similar patterns of results for school children. Recently, Barkeling et al[95] compared eating behaviors of obese and

normal-weight 11-year-olds. Obese children ate faster and failed to show the normal pattern of slowing down the rate of eating toward the end of the meal; the authors suggest that this pattern could reflect an impaired satiety signal or an impaired response to such signals. Evidence for links between eating style and adiposity appears even during infancy. Agras et al[39] found that infants with more rapid suckling during feedings at 2 and 4 weeks had greater intakes and that this sucking pattern was associated with greater skinfolds and BMI at 1 and 2 years of age. Stunkard and colleagues' recent research (unpublished observations) on genetic and environmental factors predicting infant weight gain also has shown sucking rate to be a predictor of later weight. One potentially productive area of research would investigate the extent to which children's different eating behaviors elicit different child-feeding practices.

In summary, controlling child-feeding practices can have negative and unintended effects on children's food preferences and the developing controls of food intake. It is likely that such practices foster rather than prevent the development of childhood obesity and eating problems, although additional research is needed to confirm this point. Satter[96,97] has discussed an alternative to such controlling child-feeding practices based on her extensive clinical work. She suggests a division of responsibility between parent and child; it is the parents' responsibility to supply the child with a healthful array of foods and a supportive eating context, and it is the child's responsibility to decide when and how much to eat.

Emergence of Dieting to Control Weight

By middle childhood, even before the fat deposition that occurs in girls at puberty, gender differences in weight concerns and dieting prevalence apparent in adulthood already are emerging.[98] Societal values equating physical attractiveness and thinness with femininity foster the pervasive trend of dieting among most young women, many of whom do not need to lose weight. By the age of 7, children identify overweight silhouette drawings as being less attractive, having fewer friends, and being less smart than their thin counterparts. Even before puberty, girls report a heightened sense of body dissatisfaction and a desire to be thinner, with dieting behaviors reported among children as young as 9 years of age.[99] Serdula et al[100] reported that 44% of high school girls were dieting. Although the nature of dieting behaviors in young girls is not well characterized, the potential adverse consequences of dieting on physical growth and well-being must be addressed.

Early dieting itself may constitute a risk behavior for the development of obesity. Dietary restriction involving cognitive restriction of food intake involves explicit denial of hunger cues and includes stopping eating while still hungry and skipping meals. Dietary restriction has been associated with overeating in adolescents[101] and adults.[102] Westenhoefer and colleagues[102] have suggested that restrained eating may give rise to eating binges through the weakening of satiety cues and the heightened attractiveness of food in restrained eaters. Dieting may be iatrogenic, producing the very outcome it is used to avoid. Dieting, with its self-imposed restriction, has certain parallels to controlling child-feeding practices restricting children's intake. Dietary restraint, or the intent to restrict food intake cognitively, has been associated with a number of adverse psychosocial outcomes. In a study of adolescent girls, Killen[103] found that restrained eaters exhibited high levels of worthlessness, body dissatisfaction, fear of weight gain, and disaffect, and they were heavier and were more physically developed than unrestrained girls. Similarly, Rosen et al[104] found that adolescents' restraint scores were positively associated with depression, body dissatisfaction, social anxiety, and weight status. This all suggests that attempts designed to reduce the prevalence of childhood obesity must consider the potential costs of approaches that may increase the prevalence of early dietary restriction.

CONCLUSIONS

Most experts would agree that obesity results when susceptible individuals are placed in adverse environments. To date, there have been few prospective studies of childhood obesity, and these have not tended to focus on the role of environmental factors and how they interact with genetic predispositions that affect intake and expenditure. There is extensive evidence that children's food intake is shaped by early experience with food and eating, and these findings suggest ways in which parenting practices and the family environment may be promoting obesity.

Children's eating is modified by exposure and accessibility of foods; by modeling behavior of peers, siblings, and parents; by the physiologic consequences of ingestion; and by child-feeding practices. In particular, children's liking for and consumption of foods high in energy, sugar, and fat may be enhanced by environments where those foods are present, consumed by peers or family members, and made unavailable periodically. Parental directives intended to encourage or restrict children's consumption of various foods may have adverse consequences for the development of children's food preferences and regulation of energy intake. These parental directives may even be linked to subsequent development of dieting. In particular, directives in child-feeding may discourage children's choices and focus children's attention cues other than feelings of hunger and satiety. Because parents tend to encourage children's consumption of fruits and vegetables and to limit foods high in energy, sugar, and fat, directive styles of child-feeding may negatively affect children's liking of these foods by teaching them to dislike the very foods we want them to consume and to prefer those that should be consumed in relatively limited quantities.

The findings reveal ways children's environments can be obesigenic for susceptible individuals. However, the database is very limited; the research reviewed above has focused primarily on white middle-class children of normal weight. There is little

evidence about how factors influencing children's food preferences and intake, especially child-feeding practices, may differ systematically across socioeconomic and racial groups. In addition, little research has been conducted with infants and toddlers, in whom dramatic dietary change is occurring, or with adolescents, in whom most research has focused on eating disorders and, to some extent, on dieting behavior. Both infancy and adolescence are critical periods in the development of obesity,[105] yet we know very little about the development of the controls of food intake during these periods.

The research on the developing controls of food intake in children of normal weight allows us to generate hypotheses about ways the child's genetic predispositions may interact with environmental factors to produce childhood obesity. What remains on the research agenda are tests of these hypotheses in prospective, longitudinal studies of childhood obesity, which should investigate the possibility that genetic differences contributing to obesity are manifest in individual differences in feeding and exercise predispositions and should include a joint focus on intake and expenditure (see Kohl and Hobbs).[106] Future research should include children and their families identified as differing in familial risk for obesity, in whom definitions of risk that include behavioral factors such as parenting practices, parental adiposity, and dieting history should be explored. The etiology of childhood obesity is multifaceted and requires a multidisciplinary approach, including expertise on genetics, environmental and behavioral factors, and on both energy intake and the components of energy expenditure. In cases for which double-labeled water is used to measure energy expenditure and anthropometric measures are taken over time, the validity of dietary intake measures can be addressed. The conjoint focus on children's intake and physical activity will have the added benefit of allowing us to address issues of measurement error, which is essential to advancing our knowledge base.

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Development of Physical Activity Behaviors Among Children and Adolescents

Harold W. Kohl III, PhD*, and Karen E. Hobbs, MPH‡

ABSTRACT. Physical activity is a key component of energy balance and is promoted in children and adolescents as a lifelong positive health behavior. Understanding the potential behavioral determinants necessitates understanding influences from three fundamental areas: 1) physiologic and developmental factors, 2) environmental factors, and 3) psychological, social, and demographic factors. The literature to date has generally investigated potential predictors of physical activity in children and adolescents in each of these three general areas, although existing data rely largely on cross-sectional studies in which it is difficult to distinguish a determinant from a correlate. In all likelihood, aspects of each of these three areas interact in a multidimensional way to influence physical activity in youth. This article reviews evidence of potential determinants of physical activity in children and adolescents and provides recommendations for future work. *Pediatrics* 1998;101:549–554; *youth, exercise, tracking, determinants.*

ABBREVIATION. NCYFS, National Children and Youth Fitness Study.

As indicated elsewhere in this article,[1] childhood obesity and overweight is of substantial clinical and public health concern. Physical activity is a key component of the expenditure aspect of energy balance, providing a major outlet for daily caloric usage. Cross-sectional observational and experimental intervention data suggest a significant short-term influence of exercise training on weight loss in children and adolescents,[2] although prospective observational studies designed to determine the role of physical activity in the prevention of weight gain are lacking. It logically follows that an understanding of the determinants of physical activity behavior in children and adolescents will lead to future opportunities for intervention and prevention of obesity and overweight.

From the *Baylor Sports Medicine Institute, Baylor College of Medicine, Houston, Texas, and the ‡University of Texas-Houston, Health Science Center, School of Public Health, Houston, Texas.
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Physical activity is to be encouraged among children and adolescents based largely on the assumption that the behavior will become part of the person's life and carry into adulthood, where it will help lower the risk of several chronic diseases as well as of premature mortality.[3] The underlying assumption is that there will be a positive experience in childhood or adolescence and the behavior then will track into adulthood, when it is more likely to provide physiologic benefits. Although several lines of investigation point to evidence of tracking of other cardiovascular disease risk factors, such as serum total cholesterol and systolic blood pressure,[4] data supporting the tracking of physical activity behaviors into adulthood are scarce. Given current difficulties in accurate assessment of physical activity among children and adolescents,[5] the lack of evidence for tracking physical activity may be a problem of assessment as much as it is one of tracking. Moreover, physical inactivity may be a better indicator of long-term behavior. Of additional and substantial clinical interest is evidence of a potential covariance (or co-tracking) of physical activity with obesity from childhood into adulthood, although such data are similarly lacking.

The terms physical activity and exercise are related but refer to different constructs. For the purposes of this report, we adopt the definitions of physical activity and exercise outlined by Caspersen et al.[6] Physical activity is any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above the basal level. Exercise refers to a planned, structured, and repetitive bodily movement done specifically to improve or maintain one or more components of physical fitness. Exercise is considered a subset of physical activity.

Should there be short-term health effects of physical activity in children, they most likely would be for an influence on weight loss and control. In adults, regular physical activity is associated with weight loss and maintenance. However, the relationship is more complicated in children and adolescents in that it is difficult to separate training effects (the physiologic effects of increased physical activity) on adi-

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