Laboratory-Based Studies of Eating Among Children and Adolescents

Marian Tanofsky-Kraff[1,2,§,*], Ann F. Haynos[3, §], Lisa A. Kotler[3], Susan Z. Yanovski[1,4] and Jack A. Yanovski[1]

[1]*Unit on Growth and Obesity, Developmental Endocrinology Branch, National Institute of Child Health and Human Development, NIH, DHHS,* [2]*Department of Medical & Clinical Psychology, Uniformed Services University of the Health Sciences,* [3]*Columbia University and New York State Psychiatric Institute,* [4]*Division of Digestive Diseases and Nutrition, NIDDK, NIH, DHHS*

Abstract: The prevalence of pediatric overweight has increased dramatically over the past three decades, likely due to changes in food intake as well as physical activity. Therefore, information examining eating patterns among children and adolescents is needed to illuminate which aspects of eating behavior require modification to prevent and treat pediatric overweight. Because child self-report and parent-report of children's eating habits are often inconsistent and limited by recall and other biases, laboratory-based studies in which food intake is observed and monitored have increased in number. Such studies offer objective and controlled methods of measuring and describing eating behaviors. However, to our knowledge, no publication exists that consolidates, reviews, and provides critical commentary on the literature to date in pediatric samples. In this paper, we review the literature of studies utilizing laboratory methods to examine eating behavior in samples ranging from birth through adolescence. Our review includes all relevant articles retrieved from the PubMed and PsychInfo search engines. Specifically, we examine meal-feeding studies conducted during the various developmental stages (infancy, preschool, middle childhood, and adolescence), with a focus on methodology. Included in our review are feeding studies related to dietary regulation, exposure and preference, as well as paradigms examining disordered eating patterns and their relationship to body composition. We have structured this review so that both consistent and inconsistent findings are presented by age group, and innovative methods of assessment are discussed in more detail. Following each section, we summarize findings and draw potential conclusions from the available data. We then discuss clinical implications of the research data and suggest directions for the next generation of studies of feeding behavior in children.

Keywords: Children, eating behavior, laboratory eating, feeding, food preference, energy intake.

LABORATORY-BASED STUDIES OF EATING AMONG CHILDREN AND ADOLESCENTS

Pediatric overweight has nearly tripled over the past 30 years [1] and recent research indicates that dieting and disordered eating behaviors (i.e. binge eating or purging) begin to emerge during childhood and adolescence [2-4]. Childhood overweight, as well as disordered eating patterns, have been linked to a number of physical and psychological problems [5, 6, 7]. In order to provide a sound scientific basis for the development of effective prevention and treatment strategies for both overweight and eating disturbances, studies investigating the relationship between overweight and abnormal eating patterns in children and adolescents have been conducted with increasing frequency.

A number of methods have been employed to examine the dietary intake and feeding habits of children. Most typically, 24-hour dietary recall and food frequency questionnaires have been administered to either children or their parents [8]. Unfortunately, these methods are inherently limited, as they rely on retrospective report, which can be inaccurate due to factors such as a desirability effects, difficulty with recall, or lack of nutritional knowledge.

Studies in adults have long demonstrated a discrepancy between self-reported and actual energy intake, with a tendency to underreport intake (e.g., [9, 10]). This effect may be more pronounced in children, due to recall or comprehension difficulties. Indeed, the research examining the validity of children's self-reports of energy intake indicates that children are quite often inaccurate reporters of their food intake [11-15]. Additionally, among children, recall accuracy varies according to characteristics such as age and body weight [12-14, 16, 17].

Parent-report methods are similarly imperfect. Not only are they dependent on retrospective data, but they also rely on third-party observation, and thus exclude child eating that is unobserved by parents. Studies on the accuracy of parental report generally indicate a tendency for parents to underreport children's intake [18-20]. In addition, parental and child reports of binge eating and disordered eating patterns appear to be incongruent [21-23].

Laboratory-based studies of eating during meals offer an alternative to child- and parent- report methods. Such studies allow for controlled conditions, direct observation of behavior, manipulation of target variables, and greater

*Address correspondence to this author at the Unit on Growth and Obesity, DEB, NICHD, NIH, CRC, Room 1-3330, 10 Center Drive, MSC-1103, Bethesda, MD 20892-1103; Tel: 301-451-3782; Fax: 301-480-2650; E-mail: tanofskm@mail.nih.gov
Current address: Department of Medical and Clinical Psychology, USUHS, 4301 Jones Bridge Road, Bethesda, MD 20814-4712
§*Both authors have contributed equally to this paper.*

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accuracy of intake measurement than other methods. The purpose of this paper is to review the specific methodologies and results of feeding studies conducted among children and adolescents with the aim of summarizing findings and making recommendations for future research directions. In this review, we will present cross-sectional feeding studies conducted in infancy, preschool, middle childhood, and adolescence, as well as longitudinal studies that have used feeding paradigms. We will then highlight main findings from the literature, discuss the clinical implications, and review the limitations of gathering data in a laboratory setting. This review will conclude by suggesting directions for future research.

METHODS

We conducted a literature review using electronic resources (PubMed, PsychInfo) and cross-references obtained from articles published in the English language from 1950 to the present. Search terms included: eating behavior, laboratory eating, feeding, food preference, and energy intake crossed with infant, child, and adolescent. Meal studies in which a food or caloric beverage was ingested and feeding behavior was the primary focus of the investigation were also included, regardless of the sample size. Studies in which eating patterns were recorded based upon recall or inappropriate measurement schemes were excluded. Furthermore, studies examining metabolic responses to specific diets rather than variables related to food intake were considered outside the scope of this review. A total of 91 studies were identified that fit within the parameters of the search.

RESULTS

Feeding Studies in Infancy

Seventeen feeding [24-39] studies with infant samples were identified (Table **1**). Previously-published reviews have described methods commonly used to analyze eating behavior in infancy, both subsequent to [40] and during the weaning period [41]. Most infant eating behavior studies have been carried out by a limited group of researchers and have examined a restricted range of topics, such as food preference development and disordered eating patterns in infancy. We will briefly review the methods and findings from this literature, concentrating on those studies that have not been highlighted in other reviews.

Dietary Regulation

The pioneering studies of this literature involved eating habits of orphaned infants (aged 6 to 11 months) with no prior exposure to solid foods [24, 25]. Infants self-selected three meals a day from an array of single-item unprocessed foods from the time of admission into the study until they had reached six years of age. Researchers were instructed to remain impartial during the selection process and to allow the infant to choose each meal by gesturing towards various food items. Results suggested that in such a setting, infants are able to self-select diets that sufficiently support health and growth. These findings have been interpreted as evidence for the natural ability of infants to self-select healthy, nutritious diets. However, these results should be interpreted cautiously for several reasons. Sample sizes were small; only 3 infants were studied in the 1928 study [24] and 15 infants in 1939 [25]. Further, children were tested in an artificial eating environment, as all foods offered were nutritious and social stimuli were absent [42].

Dietary Exposure

Several studies have examined the impact of flavor exposure on preference during infancy [27-30]. The nature of this developmental period presents several methodological challenges. The inability of infants to speak presents difficulties in measuring outcomes of acceptability and preference. Additionally, various modes of feeding are employed during infancy (bottle-feeding, breastfeeding, and ingestion of solid foods); thus different methods are required to expose infants at each feeding stage to various feeding experiences. Nevertheless, results generally indicate that exposure to novel flavors in infancy increases acceptability [27-30].

Exposure to various flavors is easily manipulated in studies of bottle-fed infants [40]. A number of investigators have altered formula composition according to different test variables (i.e. sweetness, salt concentration) in order to examine the effect of different flavors on infants' patterns of consumption. For instance, one study assigned 53 infants (< 3 weeks old) to different exposure groups for 7 months: a milk-based formula only, a bitter-tasting protein hydrolysate formula only, or a milk-based formula for 4 months and the bitter-tasting formula for 3 months [29]). At the 7-month follow-up, infants and their mothers participated in three test meal sessions, one with each of the assigned formulas, as well as one with a novel protein hydrolysate formula. Infant-mother feeding interactions were videotaped and flavor acceptance was measured through infant facial expressions (e.g. nose wrinkling or frowning), formula intake, and meal duration. Infants with prior history of protein hydrolysate consumption demonstrated greater energy intake, longer feeding intervals, and fewer negative facial expressions in response to both familiar and novel versions of the bitter-tasting formula than those without prior exposure. Thus, degree of prior exposure determined the level of acceptance. Similar methods have been used to examine infants' reactions to exposure to other solutions, such as sweet and salty substances (for review see Drewett & Young, 1998 [40]).

Though breastfeeding presents greater challenges to measuring the effects of dietary exposure, researchers have designed methods to alter the taste of breast milk, thus exposing breastfed infants to different flavors. For instance, Mennella *et al.* [43] were able to alter the dietary experience of breastfed infants through adjustments to their mothers' diets. Forty-six women were assigned to consume either water or carrot juice four days per week for three weeks during pregnancy and lactation. When tested at approximately 6 months of age, those infants exposed to carrot juice prenatally or through breastfeeding demonstrated fewer negative facial expressions to the carrot-flavored cereal than to the plain cereal compared to infants of mother who had not been exposed. These findings not only validated the importance of early exposure in the development of dietary preference, but also demonstrate that dietary experience may be manipulated in breastfeeding infants. Other studies have similarly documented changes in infants'

Table 1. Infant Eating Behavior Studies

Article	Age	Sample	Topic	Key finding(s)
Davis (1928) [24]	9-20 mo	3 infants	Dietary regulation	Infants efficiently regulate dietary intake.
Davis (1939) [25]	6-11 mo	15 infants	Dietary regulation	Infants efficiently regulate dietary intake.
Fomon, Filmer, Thomas, Anderson, & Nelson (1975) [26]	0-4 mo	15 infants	Dietary regulation	Infants consuming lower kcal formula ingest more food, but fewer calories than those consuming a higher kcal formula.
Birch, Gunder, & Grimm-Thomas (1998) [27]	4-7 mo	39 breast- or formula- fed infants	Dietary exposure	Exposure to a target food increases acceptance (measured via intake) of that food as well as the same food produced by a different manufacturer, and foods similar in nature.
Gerrish & Mennella (2001) [28]	~4.5 mo	48 formula fed infants	Dietary exposure	Exposure to a target food alone or with a variety of other foods increases intake of the target food. Exposure to a variety of flavors increases intake of a novel food item.
Mennella, Griffin, & Beauchamp (2004) [29]	7 mo	53 infants	Dietary exposure	Greater exposure to a bitter-tasting formula is associated with greater acceptance of that formula.
Mennella, Jagnow, & Beauchamp (2001) [43]	~6 mo	46 breastfed infants	Dietary exposure	Exposure to carrot juice in utero via mothers' consumption during pregnancy or breastfeeding period increases acceptance of carrot-flavored cereal.
Sullivan & Birch (1994) [30]	4-6 mo	36 infants	Dietary exposure	Food exposure increases acceptance of food, regardless of whether the infant is exposed to a salted or unsalted version of the food; this finding is most pronounced in breastfed infants compared to bottle-fed infants.
Chatoor, Egan, Getson, Menvielle & O'Donnell (1988) [31]	7 mo- 3 yrs	42 infants with IA, 30 control infants	Disordered eating patterns	Mothers of infantile anorexics (IA) exhibit less responsiveness and greater negative affect towards their children than control mothers during both feeding and play interactions.
Chatoor, Ganiban, Harrison, & Hirsch (2001) [32]	6- 32 mo	30 infants with IA, 30 infants with PTFD, 30 control infants	Disordered eating patterns	Infants with (IA) or Posttraumatic Feeding Disorder (PTFD) have poorer feeding interactions than healthy infants. Infants with IA exhibit less dyadic reciprocity, while infants with PTFD display greater feeding resistance and more resistance to swallowing.
Chatoor, Ganiban, Hirsch, Borman-Spurrell, & Mrazek (2000) [33]	12-37 mo	34 infants with IA, 34 picky eaters, 34 control infants	Disordered eating patterns	Compared to picky eaters and control infants, interactions between infants with IA and their mothers are characterized by the highest degree of conflict, as measured by infant food refusal and negative affect and maternal negative affect and negative comments regarding the infant.
Chatoor, Hirsch, Ganiban, Persinger, & Hamburger (1998) [34]	12-37 mo	34 infants with IA, 34 picky eaters, 34 control infants	Disordered eating patterns	Infants with IA demonstrate greater feeding conflict than picky eaters and controls. Picky eaters demonstrate greater feeding conflict than controls. Mother-infant feeding interactions in the IA and picky eating groups are characterized by more talk and distraction than controls.
Chatoor, Surles, Ganiban, Beker, Paez, & Kerzner, (2004) [35]	12-33 mo	32 infants with IA, 26 picky eaters, 34 control infants	Disordered eating patterns	Infants with IA display greater feeding and play conflict, struggle for control during eating, and less reciprocity than picky eaters or controls.
Kasese-Hara, Wright, & Drewett, (2002) [36]	12-24 mo	27 infants with failure to thrive, 26 control infants	Disordered eating patterns	Infants with failure to thrive (FTT) demonstrate poorer compensation abilities compared to controls that display accuracy in compensation following a high- or low- energy preload.
Parkinson, Wright, & Drewett (2004) [37]	13-21 mo	30 infants with failure to thrive, 57 control infants	Disordered eating patterns	Infants with FTT ingest less energy during meals and are less likely to remain in their high chair compared to controls.

(Table 1) Contd….

Article	Age	Sample	Topic	Key finding(s)
Stunkard, Berkowitz, Stallings, & Schoeller (1999) [38]	Birth- 12 mo	40 infants of obese mothers, 38 infants of lean mothers	Feeding habits & body composition	Infants at high-risk for obesity display a greater sucking rate at 3 months compared to infants at low-risk for obesity; infant weight, sucking rate, male sex and energy intake at 3 months predicts body weight and adiposity at 12 months.
Stunkard, Berkowitz, Schoeller, Maislin, & Stallings (2004) [39]	Birth- 24 mo	40 infants of obese mothers, 38 infants of lean mothers	Feeding habits & body composition	Follow up to [38]. Infant energy intake and sucking rate at 3 months predict weight gain at 24 months, after controlling for baseline weight.

breastfeeding pattern following mother's ingestion of garlic, vanilla [44], and alcohol [45, 46].

Information on dietary exposure among infants weaning to solid foods is easily measured and of particular importance as dietary experience broadens during this developmental stage. Research on infants with limited exposure to solid foods suggests that with taste exposure, acceptance of target foods increases [27, 28, 30].

Disordered Eating Patterns

Laboratory feeding studies have also described abnormal eating behavior during infancy and have allowed researchers to differentiate between various patterns of disordered eating. Chatoor and colleagues have used feeding paradigms to identify specific aberrant eating patterns. Their methodology involves mother-child feeding interactions that are videotaped and then coded by researchers to assess positive and negative feeding behaviors exhibited by both the mother and infant [32-35]. For example, a researcher may code a mother-infant feeding interaction as "dyadic reciprocity," a term that reflects positive mother-infant exchanges, or as "struggle for control," which is represented by the mother overriding the child's cues or child rejecting the food. Based upon their feeding studies, Chatoor's group has identified three categorizations of infant eating disturbance: "picky eating" is characterized by notable food refusal without growth deficiency (Chatoor *et al*. 2000); "infantile anorexia," is extreme food refusal that is accompanied by deficiency in growth and extreme parental anxiety regarding the infant's eating habits [34]; and post-traumatic feeding disorder, defined as food rejection following a trauma to the infant's alimentary canal (i.e. choking) [32]. For a complete review, see Chatoor, 2002 [47].

Another focus of research has been on the slowest-growing 5% of infants. Methods include video-recording and coding a variety of eating behaviors during typical meal-times, and comparing these observations to those of infants growing at a healthy rate. Such research has demonstrated distinct eating patterns in children who fail to thrive, characterized by reduced energy intake, poorer compensation abilities, and less compliance during feedings [36, 37].

Feeding Habits and Body Composition

Studies of only one cohort by Stunkard and colleagues have examined the relationship between eating patterns in infancy and weight status at 1 year [38] and 2 years [39] of age. In a longitudinal study, Stunkard and colleagues investigated energy intake and expenditure among 78 three-month-old infants with obese and non-obese parents in order to determine correlates with body size during the first two years of life. Infant feeding was studied in the laboratory through a nutritive sucking apparatus so that eating behavior, including milk intake and total number of sucks, could be monitored. Furthermore, child energy intake was determined from weighed food records. Children of obese parents demonstrated a greater sucking rate at 3 months than those of normal weight parents. Moreover, independent of parental weight status, energy intake at three months predicted body size and adiposity over the first two years of life. Infants with greater energy intake, as reported via 3-day weight records, and infants with a greater sucking rate at three months had higher body mass index (BMI; kg/m^2) and greater adiposity at 12 months [38] and 24 months [39], after controlling for baseline body size. These findings suggest that as early as the first months of life, specific eating behaviors may contribute to later body composition.

Summary

Controlled studies of eating behavior in infancy have been useful in identifying normative and disordered patterns of eating and in determining the effects of various dietary experiences on child body weight development. There is some indication from early data that infants possess inherent skills to regulate dietary intake, though replication of these results is needed. Food exposure during infancy also appears to have an impact on taste preference, which may indicate that infants are biologically primed for the necessary acceptance of a wide range of flavors early in life. Finally, data suggest that specific infant eating patterns may predict subsequent weight status.

Laboratory Feeding Studies in Toddlers and Preschool Children

The vast majority of controlled meal studies of pediatric eating behavior have been conducted in samples of preschool children. In total, 46 [17, 48-88] preschool feeding studies were identified (Table **2**). This period of development is particularly salient to researchers examining children's eating habits. Preschool children are considered excellent candidates for observation because they can be studied in their school environment with little intrusion into their daily habits. Moreover, the nature of this developmental stage

Table 2. Preschool Eating Behavior Studies

Article	Age	Sample	Topic	Key Finding(s)
Birch & Deysher, (1986) [48]	2-5 yrs	21 preschool children, 26 adults	Dietary regulation	Adults and children adjust caloric intake based on preload energy density; however children display greater accuracy in compensation than adults.
Birch, Johnson, Andreson, Peters, Schulte (1991) [49]	2-5 yrs	15 preschool children	Dietary regulation	Energy intake at any given meal is variable; however daily energy intake varies little.
Birch, Johnson, Jones, & Peters (1993) [50]	2-5 yrs	29 preschool children	Dietary regulation	When a lower-fat item is substituted for a higher-fat food, energy intake is reduced for the day; however children compensate for lower energy intake during the next day.
Birch, McPhee, Bryant, Johnson (1993) [51]	2-4 yrs	24 preschool children	Dietary regulation	Energy intake is not adjusted based on fat content of preloads.
Birch, McPhee, & Sullivan (1989) [52]	Exp.1: 4-5 yrs Exp.2: 2-3 yrs	Exp 1: 24 preschool children Exp 2: 20 preschool children	Dietary regulation	Children adjust energy intake based on sugar content of preloads regardless of the interval between the preload and presentation of food.
Faith, Keller, Johnson, Johnson, Pietrobelli, Matz, Must, Jorge, Cooperberg, Heymsfeld, Allison (2004) [54]	3-7 yrs	32 sibling pairs	Dietary regulation; Familial influence	Familial aggregation for energy intake, but not compensation propensity.
Hagg, Jacobson, Norlund, Rossner (1998) [55]	4-6 yrs	36 children	Dietary regulation	Children adjust dietary intake when fed milk rather than water with a meal; however, milk intake increases total energy intake of the meal.
Wilson (1994) [56]	18 mo- 5 yrs	24 preschool children	Dietary regulation	Type of milk does not affect total mealtime energy intake.
Wilson (1999) [57]	18 mo- 5 yrs	135 children	Dietary regulation	Children served chocolate milk (*vs*. plain) ingest more energy during a meal, and do not compensate for extra intake during a subsequent snack.
Johnson (2000) [58]	3-4 yrs	25 preschool children	Dietary regulation; Parental influence	Compensation abilities improve following an intervention focused on identifying internal hunger and satiety cues; children whose mother report food regulation difficulties demonstrate poor compensation skills.
Johnson & Birch (1994) [59]	3-5 yrs	73 preschool children	Dietary regulation; Parental influence; Body composition	Heavier children demonstrate poor compensation abilities. Mothers who control their children's intake have children who are less responsive to energy density cues.
Birch (1979) [60]	3-4 yrs	17 preschool children	Dietary preference	Correlation between children's preferences and food intake is stronger than reported for adults. Familiarity and sweetness of foods increase preference.
Birch (1979) [61]	3-4 yrs	17 preschool children	Dietary preference	Familiarity primarily accounts for food preference; texture and sweetness also contribute to preference.
Birch, Billman, & Richards (1984) [62]	3-5 yrs	30 preschool children and 25 adults	Dietary preference	Time of day affects the acceptability of particular foods in children, but to a lesser degree than it affects adults' acceptance of foods.
Ashraf, Schoeppel, & Nelson (1990) [88]	3-5 yrs	25 preschool children	Exposure	Children are accepting of tofu dishes that are similar to more familiar recipes.

(Table 2) Contd….

Article	Age	Sample	Topic	Key Finding(s)
Birch & Marlin (1982) [89]	Exp.1: 2 yrs Exp.2: 2-3 yrs	Exp.1: 6 preschool children Exp.2: 8 preschool children	Exposure	Preference for novel cheeses and fruits increases with increasing exposure.
Birch, McPhee, Shoba, Pirok, & Steinberg (1987) [73]	2-5 yrs	43 preschool children	Exposure	Visual exposure to novel foods increases visual, but not taste preference for the foods; taste exposure to the same foods increases both visual and taste preference.
Endres, Barter, Theodora, & Welch (2003) [63]	3-6 yrs	58 children	Exposure	Children are accepting of traditional foods enhanced with soy.
Oscarson & Braum (1999) [64]	3-5 yrs	65 preschool children	Exposure	Children were accepting of soy-based products that were similar to more familiar products.
Wardle, Cooke, Gibson, Sapochnik, Sheiham, & Lawson. (2003) [65]	2-6yrs	143 children	Exposure	Exposure to a disliked vegetable increases the acceptability of the vegetable to a greater degree than nutrition information or control.
Addessi, Galloway, Visalberghi, & Birch (2005) [66]	2-5 yrs	27 children	Exposure; Social influence	The more exposure to a novel food, the more children consume of that food; children accept and eat more of a novel food if an adult model is consuming the same food than if the model is eating a different food or not eating.
Birch, McPhee, Steinberg, & Sullivan (1990) [67]	3-4 yrs	11 preschool children	Exposure; Conditioning	Children ingest more of novel drink flavors associated with high-caloric and low-caloric drinks following a 5-week exposure period; subjective preference increases only for the high-caloric drink.
Birch, Zimmerman, & Hind (1980) [68]	3-5 yrs	64 preschool children	Exposure; Conditioning	Exposure to a familiar snack food in both a non-social and snacktime context does not increase preference for the snack; presenting food as a reward or paired with adult attention enhances short-term and long-term preference for the food.
Johnson, McPhee, Birch (1991) [69]	Exp.1: 3-4 yrs Exp.2: 2-3 yrs	Exp 1: 11 children Exp.2: 9 children	Exposure; Conditioning	Children compensate for pre-load energy density; children ingest more of novel drink flavors associated with both high-fat and low-fat drinks following 8 exposures; only the high-fat flavor intake increases significantly.
Kern, McPhee, Fisher, Johnson & Birch (1993) [70]	3-4 yrs	27 preschool children	Exposure; Conditioning	When children ingest a substantial amount of neutral-flavored shakes of varying fat content, preference increases only for the flavor associated with the high-fat shake.
Birch, Birch, Marlin, & Kramer (1982) [71]	3.5-4.5 yrs	12 preschool children	Conditioning	Using foods as a contingency for some other behavior (i.e. “eat this and then you can play”) decreases preference for the food.
Birch & Deysher (1985) [72]	3-5 yrs	Exp.1: 18 children Exp.2: 10 children	Conditioning	Children can be conditioned to associate various flavors with drinks of differing caloric density and are able to make caloric adjustments based on these conditioned associations.
Birch, McPhee, Shoba, Steinberg, & Krehbiel (1987) [73]	2-5 yrs	22 preschool children	Conditioning	Children who are encouraged to respond to internal cues display accurate compensation abilities; whereas children who receive external rewards for consumption of a meal are conditioned to eat greater amounts and respond less to density cues.

(Table 2) Contd….

Article	Age	Sample	Topic	Key Finding(s)
Birch, McPhee, Sullivan, & Johnson (1989) [53]	Exp. 1: 3-4 yrs Exp. 3-5 yrs	Exp. 1: 7 preschool children Exp. 2: 15 preschool children	Conditioning	Children who can identify cues that had or had not been paired with food are conditioned to eat in the absence of hunger.
Fisher & Birch (1999a) [74]	Exp.1: 4-6 yrs Exp.2: 3-6 yrs	Exp.1: 31 children Exp.2: 37 children	Conditioning; Familial influence	Exp. 1: Restricting children's access to a food sensitizes children to the food's external cues and increases desire to consume the food; Exp. 2: Restricting access to food increases selection and intake of the food; mothers reporting greater dietary disinhibition are more likely to restrict children's access to palatable foods.
Birch & Fisher (2000) [75]	5 yrs	197 girls	Familial influence	More maternal restriction is associated with daughter's poorer compensation abilities.
Fisher & Birch (2000) [17]	4-6 yrs	197 children	Familial influence	Parental food restriction is positively correlated with girls' consumption of restricted foods in absence of hunger and girls' negative self-evaluation of eating.
Heptinstall, Puckering, Skuse, Start, Zur-Szpiro, Dowdney (1987) [76]	4 yrs	23 children with FTT, 23 control children	Familial influence	Children who failed to thrive do not vary from control subjects in energy intake; however family mealtime is characterized by greater parental indifference, anxiety, negative affect, and meal instructions compared to controls.
Wardle, Guthrie, Sanderson, Birch, & Plomin (2001) [77]	4-5 yrs	428 children with either overweight or non-overweight parents	Familial influence	Children of overweight parents demonstrate greater preference for higher fat foods than those with non-overweight parents.
Drucker, Hammer, Agras, & Bryson (1999) [78]	3.5 yrs	77 children	Familial influence; Body composition	Maternal eating prompts (ex: number of food offers, number of food prompts) correlate with caloric intake and time spent eating.
Fisher & Birch (1995) [79]	3-5 yrs	18 children	Familial influences; Body composition	Children's fat preference is associated with degree of parental and child adiposity.
Fisher & Birch (1999b) [80]	3-6 yrs	70 children	Familial influence; Body composition	Maternal restriction of access to a snack is associated with greater consumption of the snack in the absence of hunger by girls, but not boys.
Birch (1980) [81]	2-4 yrs	39 preschool children	Social influence	Children's preference for a vegetable increases following meals with peers who preferred the vegetable; younger children are more influenced by peers' food choices than older children.
Duncker (1938) [82]	2-5 yrs	Exp. 1: 22 children Exp. 2: 25 children	Social influence	Exp. 1: Children's food choices are affected by that of their peers, particularly if the peer is older or more prestigious; Exp. 2: Children are more likely to prefer a food that the hero of a story had enjoyed, even if it was not particularly palatable.
Harper & Sanders (1975) [83]	2-4 yrs	Exp.1: 80 children Exp.2: 84 children	Social influence	Children are more likely to sample a novel food if an adult models eating the food.
Hendy (2002) [84]	3-6 yrs	8 tables of 38 children	Social influence	Acceptance of a food temporarily increases after a peer models eating the food; increase was most pronounced with female peer models.
Fisher, Rolls, Birch, (2003) [85]	2-5 yrs	30 preschool children	Portion size	Larger portions increase children's bite size, intake of entrée, and total energy intake for the meal; however, larger portions do not alter the size of children's subsequent self-selected portions.

(Table 2) Contd….

Article	Age	Sample	Topic	Key Finding(s)
Rolls, Engell, & Birch (2000) [86]	3-6 yrs	32 preschool children	Portion size	Older children, but not younger children consume more of an entrée and more total meal energy when served a larger portion.
Drabman, Cordua, Hammer, Jarvie, & Horton (1979) [87]	1.5-6 yrs	30 overweight and 30 non-overweight children	Body composition	Overweight children demonstrate higher bite rate, fewer chews per bite, and a faster eating pattern than non-overweight children.

allows for a broader examination of various influences on eating patterns. Though parents maintain a great deal of control over the eating habits of toddlers and preschoolers, children are initiating self-feeding during this time. Thus, both parental and individual child characteristics (i.e. personality traits, feelings of satiety, etc.) may influence consumption patterns. Although children are still influenced by inherent hunger and satiety cues, an awareness of the social and cultural implications of food and eating is beginning to emerge at this time. As such, observing young children provides an opportunity to investigate the effects of environment on human feeding as such influences become more prominent.

Much of the data in preschoolers are consistent with results from infant samples. For example, preschoolers are able to regulate energy intake quite effectively [67, 69, 72]. In addition, while preschool children are often food neophobic, findings indicate that the preference and acceptability of food similarly increases with exposure [67, 70, 89, 90]. Despite consistencies between infant and preschool child findings, much of the methodology used for preschoolers is distinct.

Dietary Regulation

Many studies examining preschoolers' eating behavior use methods somewhat similar to those developed by Davis and colleagues' [24, 25]. For instance, in one study of 15 preschool children, energy intake, either at home or in the lab, was measured by weighing foods before and after ingestion for six separate 24-hr periods [49]. Changes in energy intake were examined at individual meals and across various days. Findings demonstrated great variability in energy intake from meal to meal, but little variation in total daily energy intake. Using similar methods, other researchers have been able to manipulate macronutrient content, such as concentration of fat, in test meals in order to observe the effect on dietary regulation over a number of days [50]. There are strengths and weaknesses in using such methods. Twenty-four hour observations of energy intake over several different days allow a more comprehensive understanding of children's eating habits. However, the time required of participants is onerous and therefore sample sizes are often small. Additionally, data collected outside the laboratory may be imprecise.

A more commonly used method is the measurement of intake from an ad libitum lunch or snack following the consumption of a preload [51, 53, 54, 72]. This method involves observing the impact of liquid or solid preloads varying in energy or macronutrient content [51, 52] on the consumption of a free-access array of foods for lunch. Amount consumed from ad libitum lunches is examined to determine how well children adjust their intake based upon differences in preload content. Findings from such paradigms suggest that children are generally efficient at adjusting their intake based upon preloads, although the adjustment may take place over the span of more than one day [51]. Moreover, data indicate that children are more proficient than adults at adjusting their intake according to previously ingested energy content [48]. Despite such findings, other data suggest that energy compensation among preschoolers is not precise. For example, although children are able to lower their energy intake following consumption of an elevated percentage of fat in a particular ice cream, they may not reduce those calories through decreasing fat content specifically [51]. Thus, overall percentage of fat intake may increase. Studies have also demonstrated that compensation abilities vary greatly among children. Older children [58] and females [59] tend to exhibit poorer compensation abilities. Finally, compensation abilities have been shown to be inversely related to weight and adiposity [58, 59]. A genetic link in compensation abilities has also been suggested, as sibling pairs tend to exhibit similar regulatory skills [54], although such similarities may be the result of shared environmental influences.

Data suggest that proficiency in energy compensation can be learned. Johnson studied preschoolers' compensation at an ad libitum lunch following a high and low energy preload, both before and after an intervention that focused on identifying internal cues for hunger and satiety [58]. The 6-week intervention used techniques such as skits and doll playing to present strategies to help with intake regulation. Following the intervention, children demonstrated a marked improvement in caloric adjustment in response to either a high or low energy preload, independent of age or adiposity.

Dietary Preferences, Exposure, and Conditioning

While research indicates that child preference and consumption are closely linked [60], intake measurement alone may provide an imprecise method for examining preference, as it can be greatly affected by additional variables, such as environmental stimuli. The increased cognitive and verbal abilities of preschool children allow for more direct measures of preference. Many studies use a preference assessment method developed by Birch [60], in which cartoon faces (smiling, neutral, and grimacing) and researcher-assisted rankings are used to aid children in expressing food preference. This technique has been

demonstrated to capture food preferences of young children reliably. Results from such methods suggest that sweetness, texture, and, most significantly, familiarity impact the development of preferences in young children [61, 68].

While exposure increases the acceptability of novel foods by increasing familiarity [67, 70, 89, 90], research has indicated that the method of exposure is critical to altering preference [90]. In a study of 43 children, aged 2 to 5 years old, novel fruits were presented in either a "look" or "taste" condition. In the look condition, the children were visually presented, but not able to taste, novel foods. In the taste condition, children were able to both view and taste foods over a period of trials. They found that the "look" exposure only increased visual preference, while the "taste" exposure increased visual and taste preference, suggesting that the taste of a food, rather than the appearance of the food, must be familiar for taste preference to develop.

A number of studies have demonstrated that conditioning may increase food preference. For example, through repeated pairings, children can be conditioned to associate a certain flavor with the nutritional content or energy density of a food or drink [67, 69, 70]. Data suggest that children prefer flavors consistently paired with foods and drinks of higher fat content [69, 70] and energy density [67]. For example, in a sample of 3-5 year old children, Birch and colleagues paired two novel flavors (bubble gum and orange-chocolate) with a beverage of either high- or low- energy density for 8 trials over a period of 4 weeks [67]. Preference for each flavor was assessed prior to and following conditioning. Pre-conditioning flavor assessments indicated no difference in children's preference for the two novel flavors. However, following conditioning, children significantly increased their preference for the flavor paired with the drink of higher energy density [67].

Studies have also demonstrated that flavor preference can be conditioned in children by repeatedly pairing a food or flavor with a specific social context. For instance, when food has been recurrently used as a reward, has been paired with adult praise and attention, or has been withheld from a child, preference for the food as well as intake has been shown to increase [68, 74]. However, studies that use food as a contingency for a desirable behavior (i.e. "You can play the game after you eat your vegetables"), result in a decrease in preference for the food, suggesting that children develop a negative association with the food [71]. This latter finding may be explained by the "overjustification effect" which theorizes that rewarding individuals for behaviors (in this case, eating vegetables) undermines the intended goal because the action is then viewed as controlled by extrinsic factors (the vegetables are eaten for the reward only), as opposed to intrinsic variables (the vegetables are eaten because the person wants to eat them) [91]. Finally, research has demonstrated that other aspects of eating can be conditioned in young children through the context in which they are presented, including meal size [73] and, at least in children capable of understanding the cues that predict the availability of food, the initiation of a meal in the absence of hunger [53].

Familial Influences and Eating Behavior

Some feeding studies have suggested that parental variables have a significant impact on shaping preschoolers' eating habits [17, 59, 74-80, 83, 92, 93]. Specifically, parent-child interactions such as child-feeding strategies appear to influence children's eating behaviors.

In order to measure the effects of the family environment on preschoolers' mealtime behavior, many studies have examined the relationship between measures of parental weight and eating habits and the observed eating habits of their children. Findings suggest that parents who report disinhibition while eating often have children with poorer dietary regulation [58, 59] and that heavier parents tend to have children with a greater preference for, and intake of, high fat foods [79].

Other researchers have examined the relationship between parents' reports of child-feeding strategies and preschoolers' actual eating habits. A series of studies conducted by Fisher, Birch, and colleagues have examined the associations between parental restraint and control over children's intake and children's actual eating behaviors [59, 74, 75, 80]. Specifically, the construct of "eating in the absence of hunger" has garnered much interest [75]. In order to assess such eating, one paradigm involves providing children with a standard lunch, measuring satiety by depicting various states of emptiness or fullness, using pictures of cartoon figures, and then offering a fifteen minute period of free access to a large array of highly palatable foods. A child's consumption after eating a fully-satiating meal is then considered a measure of eating in the absence of hunger. Results suggest that greater parent restraint over their children's eating is associated with poorer energy regulation [59, 75]. However, whether parental restraint is causative or a response to individual children's eating patterns remains unclear.

Studies in preschool samples have also examined parent-child feeding interactions using third-party observation. One study examining 46 low-income families during mealtimes in the home setting found that, for children who fail to grow at a healthy rate, mealtimes involved less family communication and socializing and greater levels of parental anxiety or indifference [76]. A second study examined and coded videotaped laboratory feeding interactions between 77 mother-child pairs and found that children's eating rate increased with number of maternal feeding prompts [78]. Finally, Harper and Sanders [83] demonstrated that children were more likely to accept a novel food if it was offered by their mother than by a stranger. These studies are important in that they address the significance of parental behavior in the development and maintenance of children's eating habits, but they must be interpreted cautiously. Such studies are limited in that they can neither determine the degree to which genetic factors play a role between parent and child similarities in food intake, nor the extent to which individual child differences may impact parental response.

Other Social and Environmental Influences

A limited number of studies have examined the impact of social influence on the consumption patterns of young children. Both adult and peer modeling appear to affect the

eating habits of young children in that the preference for and acceptability of food increases with exposure to others' eating patterns [81-84]. Portion size also appears to influence children's food intake. Rolls and colleagues conducted a 12-week study of 30 preschoolers in which children were presented, in a counterbalanced fashion on separate days, with either an age-appropriate portion of an entrée or a large portion, which was approximately double a serving size [85]. Larger portion sizes increased the children's meal consumption, daily energy intake, and bite size. Moreover, children who ate greater amounts when presented with larger portions were also more likely to eat more in the absence of hunger (assessed using the methods previously described [17]). Given the increase in portion sizes over the past several decades [94], these findings may be particularly salient to our understanding of contributors to the current obesity epidemic.

Eating Behavior and Body Composition

The literature relating pediatric eating behavior and body composition is relatively consistent. Overweight children tend to eat faster, demonstrate poorer compensation, and endorse greater preference for fats than children of normal weight [59, 79, 87]. Studies have also examined the relationship between child body weight and observed parent-child feeding interactions. Observing and analyzing videotaped feeding interactions between mothers and children, Drucker *et al.* found that child BMI correlated with the number of maternal discouragements in the feeding context, such that children with higher BMIs had mothers who delivered more discouragements [78].

Summary of the Literature

Research examining preschoolers' eating patterns suggests that as children begin to self-feed, they continue to regulate their dietary intake reasonably well, although variability exists among children. Studies of food preference have revealed that preschool children make food preference judgments based upon their sweetness, texture, and familiarity. Preschoolers' food preferences can be altered by increasing exposure to foods, thereby making foods more familiar, by manipulating degree of satiety paired with a specific flavor, and by altering the social context in which the food is presented. Finally, based on available data, it appears that preschoolers' eating habits may be affected by familial factors, social and environmental factors, as well as individual characteristics such as body size.

Feeding Studies in Middle Childhood

Fewer data exist from feeding studies of children during the period between preschool and adolescence, or what is often referred to as middle childhood (6 to 12 years old). Twenty-one feeding studies [65, 95-114] were found that examined variables in school-aged children (Table **3**).

This literature primarily has aimed to replicate and extend findings from younger samples, and the majority of results mirror those from the literature on eating habits in preschool children. For example, 6-9 year olds are able to regulate their dietary intake efficiently, although not precisely [98]. In addition, some degree of food neophobia persists into middle childhood, though it appears to decrease with age [99, 102], and some data suggest that the acceptance of novel foods and flavors increases with familiarity of the food [102]. Middle childhood eating habits also appear to be influenced by environmental stimuli, such as parental concern and restriction of intake [98, 115]. Finally, research indicates that, similar to young children, 6 to 12 year old overweight children tend to take a greater number of bites with fewer chews per bites, eat more rapidly, and ingest greater portions compared to normal weight peers [105, 111].

In contrast to studies of younger children, a larger body of literature exists examining the relationship between body weight and abnormal eating attitudes and behaviors. This is likely the result of data suggesting that aberrant eating behaviors such as dieting [116, 117], binge eating and disturbed eating attitudes [2, 4] begin in middle childhood. As such, feeding studies in middle childhood samples shift focus from common feeding habits to an examination of intake patterns among children with different phenotypes.

Dietary Regulation

Though some evidence indicates that children demonstrate similar caloric compensation abilities across different preloads [98], other studies in middle childhood have attempted to manipulate factors related to energy intake or output in order to observe the impact on overall dietary regulation. For instance, one study manipulated the glycemic index (GI) of children's diet in order to determine the impact on subsequent eating behavior [95]. In this study, 37 middle school children (aged 9 to 12) were given 3 breakfasts varying in GI on different weeks. The children were then provided an ad libitum buffet for lunch, and intake and subjective feelings of satiety were measured. Following the low-GI breakfasts, children reported less pre-lunch hunger and ingested less energy at lunch than following the high-GI meals.

Methods have also been developed to measure effects of meal variables on dietary regulation during middle childhood. One study of 30 children between the ages of 6 and 13 involved observation and measurement of intake patterns in a camp setting [97]. Consumption of sweetened drinks was associated with an increase in children's total daily energy intake. Additionally, one study manipulated the amount of exercise, rather than a particular component of a meal, in order to determine the consequences on the subsequent ad libitum lunch and dinner consumption of 9 to 10 year old girls. The results did not indicate an increase in consumption throughout the day as a result of increased exercise [96].

Dietary Preference

In contrast to most studies of dietary preference in middle childhood that replicate findings from younger samples, a study by Epstein and colleagues [100] produced seemingly contradictory results. This study examined preference for a novel low-calorie food in 18 overweight children between the ages of 8 and 12 before and after an 8-week intervention that utilized exposure, modeling, and use of the food as a reward to increase its acceptability. Children's preferences remained stable between baseline and post-intervention measurements. This might suggest that preferences become

Table 3. Middle Childhood Eating Behavior Studies

Article	Age	Sample	Topic	Key finding(s)
Warren, Henry, & Simonite (2003) [95]	9-12 yrs	37 overweight and non-overweight children	Dietary regulation	Following breakfasts with low glycemic indexes, children report less hunger following the meal and eat less at the next meal (lunch) than those who consumed breakfasts with a high glycemic indexes.
Moore, Dodd, Welsman, & Armstrong (2004) [96]	9-10 yrs	19 girls	Dietary regulation	Over the short-term, girls' engaging in low intensity exercise ingest less energy than those involved in sedentary activity, but not high intensity exercise; however, energy intake does not differ based on exercise intensity or sedentary activity throughout the day.
Mrdjenovic & Levitsky (2003) [97]	6-13 yrs	30 children	Dietary regulation	Increased consumption of sweetened drinks correlates with increase in daily energy intake, decrease in milk intake, and weight gain.
Cecil, Palmer, Wriden, Murrie, Bolton-Smith, Watt, Wallis, Heatherington (2005) [98]	6-9 yrs	74 children	Dietary regulation; Familial influence	Younger children are able to adjust intake following a preload more effectively than older children; maternal concern regarding child's weight correlates with poorer compensation abilities.
Pelchat & Pliner (1995) [99]	3-5 yrs and 6-8 yrs	80 children	Dietary selection	Older subjects are more willing to try a novel food than preschool subjects; when given positive information about the taste of a novel food, children were more willing to taste the food.
Epstein, Wing, Valoski, & Penner (1987) [100]	8-12 yrs	16 overweight children	Exposure	Preferences for novel foods remain stable over time and are not increased by either exposure or intervention (involving using the target food as a reward paired with parental modeling).
Loewen & Pliner (1999) [101]	7-12 yrs	Exp. 1: 98 children Exp. 2: 125 children	Exposure	Age differences in response to exposure to a novel food following the sampling of another good- or bad- tasting novel food or familiar good-tasting food; older children increase willingness to try novel foods following a good tasting novel food, while younger children decrease willingness after both novel foods.
Pliner & Stallberg-White (2000) [102]	10-12 yrs	32 children	Exposure	Preference for novel foods increases with exposure to the food; children are more willing to taste a novel food when it is paired with familiar flavor.
Wardle, Herrera, Cooke, & Gibson (2003) [118]	5-7 yrs	49 children	Exposure	Preference for a novel food increases with exposure to the food; exposure increases preference compared to rewarding children for ingesting the food.
Laessle, Uhl, & Lindel (2001) [103]	8-12 yrs	38 overweight and 42 non-overweight children	Familial influence; Body composition	Overweight and non-overweight children demonstrate similar eating styles when eating alone; however, when mothers were present, overweight children eat faster, take larger bites, and accelerate their eating rate more toward the end of the meal.
Waxman & Stunkard (1980) [105]	6-13 yrs	4 families, each with at least 1 overweight and 1 non-overweight brother	Familial influence; Body composition	Overweight boys are served larger portions, eat greater amounts and more rapidly than non-overweight brothers.
Epstein, Valoski, Wing, Perkins, Fernstrom, Marks, McCurley (1989) [106]	8-12 yrs	39 overweight and non-overweight children with either overweight or non-overweight parents	Familial influence; Body composition	Child and parental weight are associated with child perception of the intensity of sweetness and fatness in foods. Following treatment, overweight children report decreased palatability of high fat and sugary foods and increased palatability of foods low in fat and sugar.

(Table 3) Contd….

Article	Age	Sample	Topic	Key finding(s)
Halford, Gillespie, Brown, Pontin, Dovey (2004) [107]	9-11 yrs	14 overweight and 28 non-overweight children	Media influence	Overweight children are more likely to recognize food advertisements and increased recognition correlates with increased intake.
Engell, Bordi, Borja, Lambert, & Rolls (1998) [108]	~10 years	33 children	Environmental influences	In a blind taste test between a high fat and a low fat cookie, children express preference for the high fat cookie; however, when provided nutritional information regarding the cookies, children with high levels of concern regarding weight and dietary intake indicate preference for the low-fat cookie.
Jansen, Theunissen, Slechten, Nedercoorn, Boon, Mulkens, Roefs (2003) [109]	8-12 yrs	16 overweight, 15 non-overweight children	Body composition	Following a preload, overweight children eat more after exposure to food cues than non overweight children.
Laessle, Uhl, Lindel, & Muller (2001) [104]	8-12 yrs	38 overweight, 42 non-overweight weight children	Body composition	Overweight children eat faster, take bigger bites, and accelerate eating towards the end of the meal when mother was present.
Overholser & Beck (1985) [110]	7-12 yrs	16 overweight, 16 non-overweight children	Body composition	Pre-treatment, overweight and non-overweight children display similar eating styles; after a treatment combining psychoeducation, modeling, and practice of weight-control techniques, overweight children take longer to consume meals, put down their utensils more often, and leave more food uneaten than before treatment.
Drabman, Hammer, & Jarvie (1997) [111]	1st- 5th grade	120 overweight and non-overweight children	Body composition	Overweight children take more bites, chew less, and take fewer chews per bite than non-overweight children.
Faith, Berkowitz, Stallings, Kerns, Storey, Stunkard 2006 [112]	5 yrs	53 children at high or low risk for obesity	Body composition	Boys at high-risk for obesity eat more in the absence of hunger than boys at low-risk for obesity.
Roemmich, Wright, & Epstein (2002) [113]	8-11 yrs	40 children	Disordered eating patterns	When stressed, children with low levels of dietary restraint reduce eating, while children with high levels of restraint increase eating.
Mirch, McDuffie, Yanovski, Schollnberger, Tanofsky-Kraff, Theim, Krakoff, Yanovski (2006) [114]	6-12 yrs	600 treatment-seeking, insulin-resistant overweight children	Disordered eating patterns	Children who endorse binge eating demonstrate shorter periods of satiety, indicate greater levels of hunger, and consume more energy during test meals than those who do not endorse binge eating.

more stable as children age. Indeed, data have revealed significant differences in exposure effects between older and younger subsets of children, suggesting that as children age they may develop more rigid schemata regarding what foods are "good" or "bad" tasting [101]. However, these results may be more indicative of differences in methodology. For instance, studies on exposure with preschool samples typically occurred in laboratory settings with children of all weight strata [68, 89]. By contrast, Epstein *et al.*'s study examined the eating behavior of overweight children in the home environment. Thus, the findings may be indicative of the impact of body composition or environmental influences, rather than age on children's food preferences.

Studies that use contingent rewards for consumption of particular foods may yield inconsistent results in preschool samples. For example, Wardle *et al*. randomized 49 children (aged 5-7 y) to one of three groups: a reward group (stickers were given for eating a novel food), an exposure-only group (children were offered foods, but received no corresponding reward), or a control group [118]. While children in the exposure group showed the greatest increase in intake and subjective ratings of novel foods, children in the reward group also demonstrated greater increases than the control

group. This result is in contrast to Epstein *et al.*'s findings [100], and may be due to differing methodological features of the two studies. For instance, the use of different types of rewards (i.e. activity vs. concrete object) as opposed to age.

Familial and Environmental Influences and Eating Behavior

Several studies have examined the mealtime behavior of school-aged children in the context of parental supervision in order to determine the impact of family environment on eating habits. Of particular interest has been the interaction between parental influences and eating behavior among overweight children. Laessle and colleagues [103] examined the eating patterns of 80 overweight and non-overweight children (aged 8-12y) via a Universal Eating Monitor (a device that permits covert continuous weighing of an individual's plate or other food reservoir by means of a concealed electronic balance) [119]; once with mother present and once unattended. Though groups exhibited similar eating patterns when unattended, when mothers were present, overweight children ate faster, took bigger bites, and accelerated eating towards the end of the meal to a greater degree compared to non-overweight children. Waxman and Stunkard also noted in their observations that overweight children are often served greater portions by their mothers than their non-overweight brothers [105]. However, this information results from anecdotal recall and has not been studied systematically in a laboratory setting.

Other environmental factors have been manipulated to examine their impact on eating in middle childhood samples. Researchers in one study altered nutritional information in order to determine the effect on snack preference on 10-year-old children [108]. Children were asked to taste and rate preference for both a high- and a low- fat version of the same cookie. One group received no nutritional information, while the other group was told the relative fat content (i.e. low-fat, high-fat) of each cookie. In the no-information group, the high-fat cookie was universally preferred, while in the nutritional information group, those children endorsing high levels of dietary concern reported a preference for the low-fat cookies.

Use of television advertising has also been manipulated in order to observe effects on subsequent eating behavior in school-aged participants. Halford *et al.* [107] presented 42 children, aged 9-11 years, with a cartoon segment interrupted by either food or non-food advertisements. Children were subsequently allowed free-access to various sweet and savory snacks. Their findings demonstrated that the increases in the number of television food advertisements recognized by children positively correlated with the amount of food consumed.

Eating Behavior and Body Composition

Many investigations suggest a link between body composition and eating behavior among children aged 6-12 years. In studies where food intake has been the primary outcome measure between overweight and non-overweight samples of children, overweight children have consistently been found to eat greater quantities of food [107, 109, 115]. In one study examining reported perceptions of the degree of sweetness and fatness in foods, overweight children's ratings indicated a lowered perception of such hedonic qualities, suggesting that heavier children may require greater food consumption to appreciate the palatable features of food and therefore become sated [106].

Data from feeding studies have demonstrated that overweight children may be receptive to behavioral interventions aimed at adapting healthier eating behaviors. Overholser & Beck [110] observed the eating habits of 16 overweight children in both a naturalistic cafeteria environment and in the laboratory, before and after a treatment aimed at improving eating behavior. The treatment combined psychoeducation, modeling, and practice to encourage children to chew more thoroughly and set down food between bites. Unlike other feeding paradigms, no significant differences were found in the observed eating styles of the overweight children and their non-overweight peers in the cafeteria setting prior to treatment. However, follo-wing the intervention, overweight children were more likely to set down their utensils between bites than their non-overweight peers (who did not participate in the intervention). This study demonstrates some degree of promise for preventative interventions geared toward correcting eating habits associated with obesity.

Dietary Restraint and Disordered Eating Patterns

Dietary restraint and disordered eating habits, such as binge eating (overeating with a feeling of loss of control over eating) appear to emerge during middle childhood [2, 117, 120, 121]. One study examined the relationship between children's dietary restraint and eating behavior in situations varying in levels of stress [113]. Forty children between the ages of 8 and 11 with either high or low self-reported levels of dietary restraint (as measured by the Dutch Eating Behavior Questionnaire; [122]) were allowed free access to an array of high-fat snack foods immediately following a situation involving high stress (giving a speech in front of peers) and low in stress (coloring). Children with high-levels of dietary restraint were more likely to increase eating following the stressful condition than those with lower restraint levels.

One study examined childhood binge eating in a laboratory setting [114]. Binge-eating behaviors were assessed via self-report questionnaire in a sample of 60 treatment-seeking overweight children between the ages of 6 and 12, all of whom demonstrated evidence of insulin resistance. These children were presented with an ad libitum buffet lunch on two different days, following either an overnight fast or a standardized breakfast. Children were verbally instructed to "Please let yourself go and eat as much as you would like. You may eat as much of anything as you would like to, but you do not have to eat anything that you do not like" at each test meal in order to elicit binge-eating behavior in the children. The food items on the array were weighed before and after the test meal in order to assess consumption. Results indicated that the children who endorsed binge eating reported a greater desire to eat and ingested more energy in both conditions. Additionally, the children who endorsed binge eating reported shorter periods of satiety following the standardized breakfast and post-fast meal. This study is the first to demonstrate binge eating behavior in children in a laboratory setting. One limitation of

this study, however, is the absence of a non-overweight control group. Further data are needed to determine whether reported binge eating in non-overweight samples would reflect similar eating behavior in the laboratory.

Summary of the Literature

Laboratory feeding paradigms among middle childhood samples have demonstrated that many factors related to eating, such as the ability to regulate intake and the acquisition of dietary preferences, remain relatively stable as children grow older. Data also suggest eating patterns may change between early and middle childhood, however the observed differences may result from inconsistency in methods employed to study these phenomena.

Feeding studies in this population have typically examined variables unique either to the environment or to child characteristics. Data suggest that the manipulation of various aspects of children's diet (such as glycemic index or beverage type) can impact subsequent energy intake. Other studies have examined the manipulation of meal context on eating patterns. Factors such as parental presence and behavior, nutritional information, and television advertisements may alter type and amount of food intake. Finally, studies have examined the relationship between eating patterns and children's body weight and reported eating-disordered behavior. These studies indicate that overweight children and those who report abnormal eating behaviors may exhibit distinct eating patterns from their non-overweight and non eating disordered peers.

Feeding Studies in Adolescents

Experimental feeding studies among adolescents are scant. A literature search on feeding studies in adolescent populations yielded only seven [99, 123-128] studies (Table **4**). From an overview of the literature, it appears that a number of investigations have examined the eating habits of teenage populations via self-report instruments, which are problematic in that adolescents often underestimate food intake on these measures [16, 129]. As such, controlled, laboratory studies on the eating behavior of adolescent samples are warranted. Presently, the majority of studies conducted among adolescent populations have addressed the impact of body weight or eating disordered attitudes on eating behavior.

Table 4. Adolescent Eating Behavior Studies

Article	Age	Sample	Topic	Key finding(s)
Ball, Keller, Moyer-Mileur, Ding, Donaldson, Jackson (2003) [123]	12-18 yrs	16 overweight adolescents	Dietary selection	Subjects have higher glucose and insulin responses and request food sooner following a meal (or meal replacement) with a high glycemic index than a meal replacement with a low glycemic index.
Ludwig, Majzoub, Al-Zahrani, Dallal, Blanco, Roberts (1999) [124]	~ 15 yrs	12 overweight adolescent boys	Dietary selection	Subjects have higher insulin concentrations and lower glucose levels following high glycemic meals; subjects demonstrate significantly greater energy intake following meals with a high glycemic index than meals with medium or low glycemic index.
Pelchat & Pliner (1995) [99]	10-14 yrs and 13-20 yrs	600 Junior high and high school students	Dietary selection	High school subjects are more willing to try a novel food than middle school subjects; when given positive information about the taste of a novel food, children, especially high school children, are more likely to taste the food.
Rolls & McDermott (1991) [125]	12-82 yrs	Adolescents, young adults, middle age adults, elderly (24 per group)	Dietary selection	Adolescents demonstrate a greater degree of sensory-specific satiety than adults of all ages.
Templeton, Marlette, & Panemangalore (2005) [126]	11-13 yrs	743 6^{th} grade students	Dietary selection	One third of all students receiving school lunches purchase competitive items; those who purchase competitive foods have lower overall energy intake, but higher fat and sugar intake and less vitamin and calcium intake, and waste more of school lunches than those who do not purchase competitive foods.
Warren, Strauss, Taska, & Sullivan (2005) [127]	Not stated	91 female high school students	Mood; Media	In an induced state of sadness, females with high levels of dietary restraint eat more after exposure to diet/body image commercials than females with low levels of restraint
Ebbeling, Sinclair, Pereir, Garcia-Lago, Feldman, Ludwig (2004) [128]	13-17 yrs	54 lean and overweight adolescents	Body composition	Overweight teens eat greater amounts of fast-food compared to non-overweight teens.

Food Choice and Dietary Composition

Effects of food choice and diet composition are salient as adolescents typically have significant control over dietary selection. Indeed, there is evidence to suggest that dietary selection in adolescence differs from other developmental periods. During adolescence, food neophobia appears to be reduced. Adolescents are more willing to sample novel foods than younger children [99]. One study also found adolescents tire more quickly of a single flavor than adults, indicating that adolescents may be particularly inclined to require greater dietary variety [125]. These studies suggest that willingness and desire to seek a variety of new foods may peak in adolescence. Thus, adolescence may be a critical period in understanding the effect of various dietary selections on consumption.

Consistent with findings drawn from younger samples, research on adolescents has demonstrated that the manipulation of dietary content, such as the glycemic index (GI), produces changes in eating patterns. Consumption of a meal or meal replacement with a low-GI has been shown to alter hormonal responses, decrease daily energy intake, and lengthen the interval before subsequent food intakes in overweight adolescents. Thus, it has been suggested that low-GI meals may decrease the degree of overweight by prolonging satiation and therefore reducing total energy intake [123, 124].

Research has also examined the effect of adolescents' food choices on eating behavior. One study examined the food selections of 743 adolescents (aged 11-13 y) in a naturalistic school cafeteria setting [126]. Researchers photographed meal trays immediately following food purchases and then at the end of the meal. Additionally, they weighed any uneaten food portions in order to estimate energy intake. They noted that approximately one third of all students purchasing school lunches also purchased some type of "competitive" add-on (i.e. soft drinks, chips, candy, etc.). Those who purchased such items had lower overall energy intake, but higher fat and sugar intake and less vitamin and calcium intake during the meal, and additionally left more school lunch uneaten than those who did not purchase competitive foods. This study relied on photographs to estimate meal size prior to consumption, thus it is limited by the absence of more objective measures. However, it does provide initial direct evidence that competitive foods may promote poorer overall eating habits.

Fast food may also contribute to poorer eating habits in adolescent samples. In a study by Ebbeling *et al.* [128], overweight and lean adolescents were served extra-large portions of fast-food (with allowance for refills) for lunch in a naturalistic food-court setting and energy intake was measured. The adolescent subjects ate an average of 1652 kcals during this meal, which was more than 60% of their estimated total energy expenditure. These studies suggest that dietary selection has a significant impact on the eating habits of children during their teen years.

Influences of Mood, Media, and Dietary Restraint

In one study, researchers manipulated mood and media exposure in order to measure the effects of eating patterns on the eating behavior of 91 high-school females [127]. Subjects were categorized as demonstrating either high or low levels of dietary restraint by virtue of scores on self-report measures. Both groups were exposed to a sad film clip, which was designed to evoke negative emotions. This clip was intermittently interrupted by either diet- and body image-related or neutral advertisements. During the viewing, subjects were given free-access to snack foods, and intake of these foods was measured at the completion of the experiment. While both groups ate similar amounts in the neutral condition, females with high levels of dietary restraint ate nearly twice as much after exposure to commercials regarding diet and body image than females with low levels of restraint. This study illustrates the complexity between individual (i.e. eating pattern, mood) and environmental (i.e. media) factors on eating behavior during the period of adolescence.

Body Composition and Eating Behavior

Though limited in number, feeding studies have also observed eating behavior of overweight and non-overweight samples of adolescents in order to examine the relationship between body weight and adolescent eating patterns. One example is Ebbeling *et al.*'s study which found that overweight adolescents ate greater amounts than non-overweight teens when presented with a fast-food meal [128].

Summary

Though sparse, studies that make use of feeding paradigms provide information that may be useful in elucidating factors that contribute to adolescent overweight and disordered eating behaviors. Dietary selection in particular may have bearing on eating behavior and body weight. Poorer food choices may lead to decreased satiation or heightened temptation to overeat and thus ultimately result in greater energy intake. Media influences and dietary restraint may also impact adolescent eating behavior. Further research on adolescents is required to better characterize eating during this developmental period and to better clarify the relationship between body weight, distorted cognitions, and eating behavior.

Longitudinal Studies of Eating Behavior

A limited number of studies have examined eating behavior prospectively (Table **5**) [92, 93, 115, 120, 130, 131][1]. Such studies constitute an important piece of the literature, as they are able to provide information regarding how feeding habits vary throughout childhood and adolescence. Further, such studies allow careful examination of precursors to and influences on future eating habits and body weight.

Only one study has longitudinally examined the patterns of eating earlier in life (from birth to 5 years) in order to determine whether "picky eating" in infancy translated into eating changes later in childhood [130]. Results indicated that compared to children without a "picky eating" style (based upon parent report), those with picky eating at age 2 and 4 weeks exhibited fewer sucks per feeding session, and

[1]Two additional studies by Stunkard *et al.* [38, 39] are described in the section on infant feeding paradigms.

Table 5. Longitudinal Studies[2]

Article	Age	Sample	Topic	Key finding(s)
Jacobi, Agras, Bryson, & Hammer (2003) [130]	Birth- 5.5 years	135 infants	Longitudinal	Infant's "picky eating" (as reported by parents) correlates with less dietary variety seeking over time. Girls with "picky eating" exhibit different sucking behavior in infancy and decreased caloric intake between the ages of 3.5 and 5.
Birch, Fisher, & Davidson (2003) [92]	5-9 yrs	140 girls	Longitudinal	Frequency of "eating in the absence of hunger" increases between the ages of 5 and 9 years. Restrictive maternal feeding practices and daughter's weight at 5 years are linked to "eating in the absence of hunger" at ages 7 and 9.
Fisher & Birch (2002) [115]	5-7 yrs	191 girls	Longitudinal	"Eating in the absence of hunger" is moderately stable over time; parental restriction of 5-year-olds' access to food predicts "eating in the absence of hunger" at age 7.
Francis & Birch (2005) [93]	5-9 yrs	171 girls	Longitudinal	Overweight mothers' restrictive feeding practices of 5 yr old daughters predicts "eating in the absence of hunger" at ages 7 and 9 years; "eating in the absence of hunger" predicts increases in BMI between 5 and 9 years.
Shunk & Birch (2004a) [120]	5-9 yrs	153 girls	Longitudinal	Girls at risk for overweight at age 5 are prospectively at risk for dietary restraint, disinhibited eating (as measured by "eating in the absence of hunger" in the laboratory), weight concerns and excessive weight gain from ages 5 to 9 years.
Shunk & Birch (2004b) [131]	5-9 yrs	153 girls	Longitudinal	Reported dietary restraint does not correlate with actual intake at ages 5, 7 or 9 years.

at ages 3 and 5 years ate fewer foods and were more likely to avoid vegetables. For girls with picky eating, energy intake was decreased between 3 and 5 years of age, while all other children increased energy intake.

Birch and colleagues have conducted several longitudinal studies with samples of girls between the ages of 5 and 9 years [92, 120, 131]. Each measured body composition and obtained self-report of dietary patterns and objective measures of energy intake at 5, 7, and 9 years. Significant correlations were found between parent's reported restriction of child's food intake and child's weight at 5 years. BMI at 5 years and behavioral measures of girls' dietary restriction were also associated with eating in the absence of hunger at 7 and 9 years [92, 120]. One study found that while girls who endorsed dieting and greater amounts of dietary restraint reported lower food intakes during 24-hr recalls at the ages of 7 and 9, their actual intake did not vary from that of less-restrained girls at any time point during laboratory eating situations [131]. It may be that as girls become older, endorsements of dietary restraint are more indicative of a desire to restrict food intake than any actual change in behavior.

IMPLICATIONS AND FUTURE DIRECTIONS

Clinical Implications

Based upon the findings of our review of pediatric feeding studies, the literature has provided insights into the eating habits of children that may offer clinically relevant implications. Since young children appear to possess some intrinsic ability to regulate energy intake, such abilities might be targeted to promote continued healthy eating patterns. Limited data already support the efficacy of such interventions in young children [58]. Although research is required to further illuminate precisely which cues allow young children to effectively regulate energy intake, clinicians should help children maintain their natural abilities by training them to focus on internal cues, rather than the external influences that seem to impact energy regulation in older children.

The literature also suggests that many children may be resistant to trying unfamiliar foods. However, strategies such as exposure and conditioning have been shown to increase acceptance of and preference for new foods. Exposure to a range of healthy foods (for example, fresh fruits and vegetables, lean meats and dairy products) in early childhood may positively impact the quality of dietary intake as children grow. Such an intervention would require that parents, caretakers, and schools provide children with an array of nutritionally rich food choices at a young age in order to aid in developing early food preferences that promote healthy diets.

Both home and community environments appear to have a profound effect on children's eating habits. The parental behaviors most consistently linked to less healthful eating habits in children are food restriction and controlling mealtime behavior. Although it is possible that these associations are primarily a reflection of appropriate parental responses to past child behaviors that have been interpreted by parents as leading to excessive energy consumption, another interpretation of these findings is that placing extensive limitations on children's eating habits may inhibit their abilities to interpret their own hunger cues. Future studies are required to illuminate the genetic versus familial

[2]Two additional studies by Stunkard *et al*. [38, 39] are described in the section on infant feeding paradigms.

and environmental effects of food intake that may promote or protect against obesity.

Finally, limited data have suggested that children who report aberrant eating behaviors overeat in the laboratory. Targeting disordered eating patterns such as binge eating or overly restrictive dieting may serve as an intervention to reduce poor eating habits and possibly promote healthier weight in overweight children or to prevent weight gain in those at risk for overweight.

Future Research

Despite the significant advances in our understanding of the variables affecting children's energy intake documented in this paper, we believe there are several significant lacunae that can be addressed by future research studies. One area of importance is subject selection. Much of the pediatric feeding study literature has relied on Caucasian, female samples. Therefore, future studies with more diverse samples are required. In particular, longitudinal data are warranted to determine how earlier eating patterns impact later eating habits and future weight gain among diverse samples. Such investigations will likely provide a greater understanding of the potential direction of causality between parent behaviors and environmental stimuli and childhood eating patterns.

The literature including adolescent samples is sparse. Adolescence is a developmental period marked by physical, social, and emotional changes. While the eating behaviors of pre-school youth and those in middle childhood are primarily under parental influence, adolescents typically have greater control over their food choices and eating habits. Adolescence is also the period when many abnormal eating behaviors such as restrictive dieting, binge eating, and other disordered eating patterns may start. Furthermore, overweight adolescents are being increasingly targeted for new weight reduction treatments. It is thus crucial to characterize the eating behaviors of this cohort with the aim of targeting eating patterns promoting disordered eating and overweight for prevention or intervention. Finally, further study is required to determine similarities and differences in eating behavior between teens and younger cohorts and to pinpoint the unique impact of this developmental stage on eating patterns.

Another area of investigation that is required involves broadening our understanding of the relative impact of physical and genetic factors in food intake. Indeed, studies in adult samples suggest that both individual and genetic contributions significantly contribute to eating patterns [132, 133]. Studying eating behavior in relation to the brain, gut, adipocyte and other biological factors, acting peripherally or centrally, may provide important information about dietary intake and body weight. Moreover, because inactivating mutations of leptin, the adipocyte-derived hormone, or of leptin's hypothalamic signal transduction pathway including the leptin receptor, the pro-opiomelanocortin (POMC) gene, the processing enzymes needed to make alpha-MSH from POMC, and the melanocortin 4 receptor (MC4R) have been related to body weight [134-136], further feeding studies should include a genetic analysis component. Other genes of potential interest include ghrelin and the ghrelin receptor, neuropeptide Y (NPY) and NPY receptors, the cholecystokinin A-type receptor, the orexins and orexin receptors, the cocaine-amphetamine related transcript (CART), and the melanocortin 3 receptor because they may play a role in transducing or modifying leptin signaling in the hypothalamus.

Another area that warrants investigation is the use of ecological momentary assessment (EMA) both during feeding studies and to supplement data collected in the laboratory. Since EMA involves recording information in real-time, data, such as mood states, may be collected in laboratory. Outside of the artificial paradigm where intake is not typically measured by a third person, data with regard to food intake, mood, and other circumstances may be easily captured using personal digital assistants in naturalistic settings. Such research may offer a greater understanding of eating behaviors throughout an extended time period, as opposed to simply data collected during a laboratory meal. Such research on eating disordered behaviors and affective states in adults have already effectively made use of EMA [137-139]. Furthermore, despite concern that children may have difficulty using personal digital assistants, EMA research has been conducted in youth with affective disorders [140, 141] and in studies of smoking cessation [142, 143] and physical activity [144].

Further research is also required to examine the impact of disordered eating behaviors on actual intake. For example, more data examining binge eating are required to better understand its impact on energy intake in healthy weight and overweight children. Other areas requiring exploration include the impact of eating in response to negative affect and other psychological variables on dietary patterns. Such data may illuminate factors involved in the development of excessive weight gain and eating disorders. Finally, the effect of interventions, such as behavior modification or pharmaceutical treatment, on eating patterns warrants future examination.

Limitations

Although there is much advantage to measuring eating behavior in a controlled setting, the limitations of such methods should be noted. Artificial circumstances, such as those in the laboratory, may alter the eating patterns of children as a result of desirability and demand characteristics. Some studies have sought to reduce this effect by covertly observing children in a naturalistic setting or by having researchers join children for several meals prior to testing days in order to acclimate children to their presence. Psychological reactance, a theory suggesting that when the freedom of options is limited, the attractiveness of the available options is decreased [145], might also impact feeding studies. If children feel forced to eat a limited variety of foods, a dislike for the target foods might develop. Moreover, in order to manipulate experimental circumstances and reduce extraneous variability, feeding studies may create an artificial mealtime setting, thus bringing into question whether such results are generalizable outside of the experimental conditions. Finally, the methods and settings (i.e. laboratory, home, school) utilized in the literature to date have varied greatly across studies, often making direct comparisons of results challenging.

In conclusion, the literature to date indicates that feeding paradigms are a viable and informative approach to studying eating behavior in the laboratory. Data collected from such studies are imperative for our efforts to reduce the current rates of obesity.

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