American Dietetic Association

Review

RESEARCH

Meets Learning Need Codes 5000, 5180, 9000, and 9020. To take the Continuing Professional Education quiz for this article, log in to ADA's Online Business Center at www.eatright.org/obc, click the "Journal Article Quiz" button, click "Additional Journal CPE Articles," and select this article's title from a list of available quizzes.

Food Selectivity and Sensory Sensitivity in Children with Autism Spectrum Disorders

SHARON A. CERMAK, EdD; CAROL CURTIN, MSW; LINDA G. BANDINI, PhD, RD

ABSTRACT

Autism spectrum disorders comprise a complex set of related developmental disorders that are characterized by impairments in communication, social interaction, and repetitive behaviors. Impairments in sensory processing are also extremely common. The prevalence of autism spectrum disorders is increasing and is currently estimated to affect 1 in 150 children. Autism spectrum disorders are considered to be a major health and educational problem, affecting many areas of daily living, including eating. Children with autism spectrum disorders are often described as picky or selective eaters. This article provides a comprehensive narrative review of the empirical literature over the last 25 years on food selectivity and nutritional adequacy in children with autism spectrum disorders. The possible contributions of sensory factors, such as sensory sensitivity, to food selectivity are discussed. The need for an interdisciplinary approach to managing atypical eating patterns in children with autism spectrum disorders is highlighted.

J Am Diet Assoc. 2010;110:238-246.

S. A. Cermak is a professor in the Division of Science and Occupational Therapy, University of Southern California, Los Angeles; at the time of the writing of this article, she was the director of Occupational Therapy Training at the UMMS-Shriver Center Leadership Education in Neurodevelopmental Disabilities (LEND) Program, University of Massachusetts Medical School, Waltham, MA. C. Curtin is a research assistant professor in Family Medicine and Community Health at the University of Massachusetts Medical School—E. K. Shriver Center, Waltham, MA. L. G. Bandini is an associate professor of pediatrics, University of Massachusetts Medical School—E. K. Shriver Center, Waltham, MA, and clinical professor, Department of Health Sciences, Boston University, Boston, MA.

Address correspondence to: Sharon A. Cermak, EdD, Division of Science and Occupational Therapy, University of Southern California, 1540 Alcazar St, Los Angeles, CA 90033. E-mail: sharon.cermak@gmail.com

Manuscript accepted: July 28, 2009.

0002-8223/10/11002-0006$36.00/0

doi: 10.1016/j.jada.2009.10.032

Early childhood is a period when children experience new foods, tastes, and textures. Parents of toddlers and young children often describe their children as "picky eaters" who refuse to try or eat a variety of foods. Although picky eating is not uncommon among young children who are typically developing, pickiness in children with autism spectrum disorders may be even more restrictive and may extend beyond the early childhood period (1-3).

Autism spectrum disorders are life-long neurodevelopmental disorders characterized by impairments in three domains of functioning: social behavior; communication abilities; and restricted, repetitive, or stereotyped patterns of behavior. Autism spectrum disorders currently affect 1 in 150 children in the United States (4), a prevalence that has quadrupled in the last 20 years. The implications of this rise in prevalence is on the scale of an epidemic, but as yet no definitive cause has been determined, and the efficacy of specific interventions are not yet clear. Parents of children with autism spectrum disorders report many challenges with children's daily activities, behavior, and communication. Parents also frequently express concern related to meal times.

Parents of children with autism spectrum disorders often report that their children are highly selective eaters, with very restricted repertoires of food acceptance, which can be limited to as few as five foods. Management of food selectivity and concerns about dietary adequacy have been found to be major reasons for referral of children for nutrition services (5). Picky eating, also referred to as *food selectivity*, is a considerable problem because it can be associated with inadequate nutrition as a result of the restricted diet (6-12).

Despite considerable anecdotal evidence and case reports to support that food selectivity is a substantial problem in children with autism spectrum disorders, only a few empirical studies have compared food intake and eating patterns of children with autism spectrum disor-

ders to those of typically developing children or other clinical populations. Furthermore, food selectivity has not been operationally defined in a consistent manner and has been used to refer to picky eating, frequent food refusals, limited repertoires of foods, excessive intake of a few foods, and selective intake of certain food categories, such as carbohydrates. In this narrative literature review, studies that have examined the phenomenon of food selectivity and nutritional intake in children with autism spectrum disorders are reviewed. Numerous anecdotal reports and autobiographies of individuals with autism spectrum disorders suggest that sensory factors, such as smell, texture, color, and temperature, can contribute to food selectivity. Thus, we have included in our review the literature on sensory sensitivity in children with autism and explore how this may be an important dimension in understanding food selectivity. This article concludes with a discussion of the need to understand food selectivity in this population and the importance of an interdisciplinary approach in addressing the needs of children who demonstrate substantial food selectivity.

METHODS

The search used the electronic databases of Medline, Cinahl, PsychInfo, and Web of Science to locate pertinent literature published in English in the last 25 years. In the food selectivity and nutrient intake sections, search term combinations included a population term (eg, *autism, autism spectrum disorder, Asperger, pervasive developmental disorder*) and a food-related term (eg, *food, feeding, mealtime, selectivity, picky, eating, nutrient, nutrition*). In the sensory processing section, the population term was combined with a sensory term (eg, *sensory, reactivity, response, tactile, oral, gustatory, olfactory*). Reference lists of the articles obtained were manually searched for additional references. Studies with empirical data were included; single-subject intervention studies designed to modify eating behavior were not included, nor were case studies. A limited number of research studies on food selectivity in children with autism spectrum disorders were identified. This included 12 articles, five without a comparison group, four with a typical comparison group (two used the same sample), and three with a special needs comparison group. An even more limited number of studies on nutritional status/diet adequacy in children with autism spectrum disorders were identified; three studies were identified that did not include a comparison group, and four studies included a control group with typically developing peers. Of these studies, three examined both food selectivity and nutritional adequacy. Almost all studies were based on food records, questionnaires, or interviews involving parent report. Only one study observed actual food intake in which the type of food was manipulated. Because of the small number of studies, all were included in the review. (See Tables 1 and 2 for a summary of studies.) Parent and client reports using books, Web sites, and contacts with individuals with autism were also examined to provide anecdotal reports to illustrate points.

Food Selectivity in Children with Autism Spectrum Disorders

Studies examining food selectivity in children with autism spectrum disorders included those with an autism spectrum disorder group only, those with a typically developing comparison group, and those with a comparison group of children with other special needs. In the United Kingdom, Cornish (6) examined the diets and weight status of 17 children with autism spectrum disorders, ages 3 to 10 years, and found that 10 of the 17 children (59%) ate fewer than 20 different foods. In a survey sent to parents of 43 children and adolescents with autism spectrum disorders 4 to 26 years about dental treatment, oral hygiene behavior, and nutrition, including food preferences and eating patterns, Klein and Nowak (13) found that 53% of the participants were reported to be reluctant to try new foods. Williams and colleagues (12) surveyed 100 parents of children with autism spectrum disorders ages 22 months to 10 years; 67% of the parents reported that their child was a "picky eater," despite the fact that nearly three quarters (73%) reported that their child had a good appetite for foods that they liked. This suggests that picky eating is not associated with a lack of appetite. The authors reported that the factors parents felt influenced food selectivity were texture (69%), appearance (58%), taste (45%), smell (36%), and temperature (22%). The most frequently reported eating and oral behavior problems were reluctance to try new foods (69%), resistance to taking medicine (62%), eating too few foods (60%), mouthing objects (56%), and rituals surrounding eating (46%). Similarly, in a qualitative analysis of parent reports of 100 children with autism spectrum disorders (79 children with autism, 21 with Asperger syndrome) ages 2 to 16 years, Whiteley and colleagues (14) found that 83% of parents reported that their child ate a restricted repertoire of foods as their core diet. Physical texture or consistency of food was often cited as the underlying factor in the choice of foods, although characteristics of food such as brand, product name, or packaging/wrapping, were also reported as determining factors. Although these studies indicate that a high percentage of children with autism are selective eaters, lack of a comparison group makes it difficult to tell whether these characteristics were more prevalent in children with autism spectrum disorders than in a sample of children typically developing.

Raiten and Massaro (10) published one of the first studies designed to compare the dietary intakes of children with autism spectrum disorders and typically developing children. In their study of 40 children with autism spectrum disorders and 34 typically developing children, the authors found that children with autism spectrum disorders were more likely to adhere to the same foods and to show more food preferences than their typically developing peers. However, no statistical analyses were reported to indicate whether these differences were significant.

In a more recent and larger scale study, Schreck and colleagues (15) compared food selectivity in 138 children with autism spectrum disorders and 298 typically developing controls, ages 7.0 to 9.5 years. Parents completed a food preference inventory developed by the authors to assess the extent to which children ate a variety of foods. Parents of children with autism spectrum disorders re-

Table 1. Summary of research on food selectivity in children with autism spectrum disorders

Author(s), year	Participants	Age (y)	Method
Ahearn and colleagues, 2001 (20)	Autism and PDD-NOS[c] (n=30)	3-14	Laboratory-based
Cornish, 1998 (6)	ASD[a] (n=17) No comparison group	3.6-9.9	3-day dietary recall; food frequency checklist
Dominick and colleagues, 2007 (19)	ASD (n=67) Language-impaired (n=39)	4-14	Parent interview
Field and colleagues, 2003 (17)	ASD (n=26) DD[b] (n=225)	1 mo-12 y	Retrospective chart review
Klein and Nowak, 1999 (13)	ASD (n=43) No comparison group	4-26	Parent survey
Raiten and Massaro, 1986 (10)	ASD (n=40) Typically developing (n=34)	ASD: 10.6±4.3[d] Typical: 8.8±4.8[d]	7-day food record; Questionnaire to measure parental attitudes, beliefs, and knowledge of nutrition
Schmitt and colleagues, 2008 (11)	ASD (n=20) Typically developing (n=18)	7-10	Parent questionnaire; 3-day food record
Schreck and colleagues, 2004 (15)	ASD (n=138) Typically developing (n=298)	7-9.5	Food Preference Inventory; Children's Eating Behavior Inventory
Schreck and Williams, 2006 (16)	ASD (n=138)	4.4-12.6	Food Preference Inventory; Children's Eating Behavior Inventory
Whiteley and colleagues, 2000 (14)	ASD (n=100) No comparison group	2.3-16.2	Parent report
Williams and colleagues, 2000 (12)	ASD (n=100) No comparison group	1.8-10	Parent survey
Williams and colleagues, 2005 (18)	ASD (n=64) DD (n=45) Typically developing (n=69)	2-12.4	Parent report; Food frequency questionnaire; 3-day food record

[a]ASD=autism spectrum disorders.
[b]DD=developmental disability.
[c]PPD-NOS=pervasive developmental disorder not otherwise specified.
[d]Mean±standard deviation.

ported that their children refused considerably more foods and had a less varied diet than did parents of children without autism spectrum disorders. In addition, the children with autism spectrum disorders were reported to eat fewer foods within each food group category; in general, children with autism spectrum disorders ate about half the number of foods in each food group except starches, where they ate about two thirds the number of foods as typically developing children. Children with autism spectrum disorders also were considerably more likely to accept only low-texture foods, such as those that had been puréed. The authors concluded that children with autism spectrum disorders had a substantially greater degree of food selectivity than typically developing children. Using the same data set in a subsequent analysis, Schreck and colleagues (16) reported that most of the restricted food intake in children with autism spectrum disorders could be attributed to food presentation, such as different food items touching on a plate or specific utensil requirements. Across all food groups, children with autism spectrum disorders ate fewer types of foods than did other members of their family. However, food preference (as defined by the number of different foods eaten) was also found to be related to the family's food preferences. In this study, as in the other studies described here, food selectivity remained broadly defined, and food texture was not defined.

In a study to examine eating behaviors and nutrient intakes of children with autism spectrum disorders, Schmitt and colleagues (11) asked the parents of 20 boys with autism spectrum disorders and 18 typically developing boys ages 7 to 10 years to complete a questionnaire on eating behaviors and food preferences and a 3-day food record. Boys with autism spectrum disorders ate a considerably smaller variety of foods than controls (17±6 vs 22±6 during a 3-day period) and more often made their food choices based on texture than did the boys in the control group. Seventy percent of children with autism chose their food based on texture, compared to 11% of children without autism. In addition, parents of boys with

Table 2. Summary of research examining nutritional adequacy of dietary intake in children with autism spectrum disorders

Author(s), year	Participants	Age (y)	Method
Cornish, 1998 (6)	ASD (n=17) No comparison group	3.6-9.9	3-day dietary recall; food frequency checklist
Herndon and colleagues, 2009 (8)	ASD (n=46) Typically developing (n=31)	2.5-8	3-day food record
Ho and Eaves, 1997 (21)	ASD (n=54) No comparison group	13.3[c]	3-day food record
Levy and colleagues, 2007 (22)	ASD (n=52) No comparison group	3-8	3-day food record
Lockner and colleagues, 2008 (9)	ASD (n=20) Typically developing (n=20)	3-5	3-day food record
Raiten and Massaro, 1986 (10)	ASD[a] (n=40) Typically developing (n=34)	ASD: 10.6±4.3[b] Typical: 8.8±4.8[b]	7-day food record Questionnaire on attitudes and beliefs about nutritional knowledge
Schmitt and colleagues, 2008 (11)	ASD (n=20) Typically developing (n=18)	7-10	Questionnaire 3-day food record

[a]ASD=autism spectrum disorder.
[b]Mean±standard deviation.
[c]Mean age.

autism spectrum disorders reported having greater difficulty getting their child to eat. Boys with autism spectrum disorders also had a particular aversion to mushy food. However, the authors did not provide any specific information on how they categorized food to determine variety or how they defined mushy foods because the sensory characteristics of "mushy" food are not clear. In addition, there were no diagnostic criteria for autism; it was determined by parental report.

Several studies have compared food selectivity in children with autism spectrum disorders to that of children in other clinical populations. In a retrospective chart review of 349 children ages 1 month to 12 years referred for a feeding evaluation (225 had developmental disabilities, 26 had autism spectrum disorders), Field and colleagues (17) found that the prevalence of food selectivity by type of food was considerably higher for children with autism spectrum disorders than the other children in the study. However, information was obtained from a chart review based on interdisciplinary team evaluations and medical records, but no specific information was provided on how assessments were made.

In another study on food selectivity in children with autism spectrum disorders and other developmental disabilities, Williams and colleagues (18) conducted a review of 178 children with and without developmental disabilities, ages 2 to 12 years, referred to a feeding program for selective eating. The sample included three groups: typically developing (n=69), autism spectrum disorders (n=64), and other special needs (n=45). The evaluation incorporated a food frequency questionnaire that asked parents to report how many foods their child had eaten and also included a 3-day food record. The authors did not find differences between groups in the types or variety of foods consumed. However, the authors categorized their data by food group and did not appear to assess the numbers of different foods independent of food group that the child ate. Furthermore, all the children studied were referred for selective eating; therefore, it cannot be determined whether picky eating is more common in children with autism spectrum disorders.

Using a parent interview, Dominick and colleagues (19) studied the prevalence of atypical behavior, including atypical eating behavior, in 67 children with autism spectrum disorders and 39 children with a history of language disorders, ages 4 to 14 years. Atypical eating behavior was defined as food refusal, selectivity, or unusual behaviors or rituals associated with mealtimes. In the sample of children with autism spectrum disorders, more than three quarters showed atypical eating behavior, compared with only 16% of the children with a history of language disorders. Sixty-three percent of the children with autism spectrum disorders were reported to eat a restricted range of foods. More than 30% of parents of children with autism spectrum disorders reported that their child showed a preference for food based on textures. Problems were reported to have begun in the first year of life, with almost all the children demonstrating these behaviors before age 3 years. At the time of the study, 88% of children continued to have atypical eating problems, indicative of a persistent problem.

Whereas the studies reported above all were based on parent report, Ahearn and colleagues (20) conducted a laboratory-based observational study of food acceptance in 30 children, ages 3 to 14 years, with autism or pervasive developmental disorder not otherwise specified. Children were seen for six separate sessions during which time their acceptance of 12 foods from four different categories of food (ie, fruit, vegetable, starch, or protein) was assessed. Each session consisted of six consecutive pre-

sentations of each of four food items, one from each category. One of the four foods was offered in a pureed form. Food acceptance was determined and categorized as low, moderate, or high, depending upon the number of bites of food the child took. Food selectivity was classified as overselective, moderately selective, or mildly selective, based on bites accepted within a food group. There was also an additional category for texture selectivity. Seventeen of the children were categorized as having low food acceptance, and 17 were categorized as being selective for either food type or texture. The authors reported that the findings were significant based on a χ^2 analysis. These findings support the hypothesis that food selectivity is high in children with autism spectrum disorders. The authors point out that food was offered as bites rather than servings, which may have altered acceptance. In addition, four children refused all foods presented during the assessment; however, these children were reported to accept at least two of the food items at other times. It was suggested that this discrepancy may have been the result of a new environment with unfamiliar staff and an unusual feeding procedure.

The studies described here indicate that food selectivity is a significant problem for many children with autism spectrum disorders. However, the lack of a clear definition of food selectivity, the small numbers of children in most of the studies, and the lack of a control group make it difficult to draw conclusions regarding the magnitude and impact of the problem.

Food Selectivity and Nutritional Adequacy

Restricted intakes of food can lead to nutritional insufficiency if the types and variety of foods remain restricted. This makes food selectivity a potential health risk. However, despite the widespread concern over food selectivity in children with autism spectrum disorders, only a few studies have actually assessed the nutritional adequacy of these children's diets and they have revealed mixed findings. Two of the studies that reported a high degree of food selectivity in children with autism also assessed the nutrient adequacy of the children's diet. Raiten and Massaro (10) analyzed a 7-day diet record for 40 children with autism spectrum disorder and 34 typically developing children. They also assessed caregivers' perceptions of their children's eating habits and clustered these into the categories of sameness, specific eating behaviors, and specific food preferences. Despite the fact that there were higher numbers of children with autism spectrum disorders in each cluster, they found no difference in the adequacy of the nutrient intakes between the two groups. However, overall adequacy of the diet based on nutrient needs was not provided.

In a small study, Schmitt and colleagues (11) compared the nutrient intake of 20 boys with autism and 18 controls 7 to 10 years of age using a 3-day food diary. There was no difference in nutrient intake between the two groups, although as noted earlier, the eating behaviors differed among the boys with autism spectrum disorders and the controls. In another small study of children ages 3 to 5 years with and without autism spectrum disorders, Lockner and colleagues (9) found that most children met the EARs for selected nutrients. However, a greater proportion of children with autism spectrum disorders was below the EAR for vitamin A.

In contrast, Cornish (6) reported inadequate nutrient intakes in children with autism based on a 3-day dietary recall and a food frequency checklist. Nine of 17 children with autism (53%) had intakes that were below the recommended intake for one or more nutrients. There was an inverse relationship between variety and nutritional adequacy; as the daily variety decreased, the number of nutrient intakes that fell below the recommended amount increased. Intake of protein, vitamin A, thiamin, vitamin B-12, folic acid, sodium, potassium, magnesium, phosphorous, and copper were determined to be adequate for all children. Inadequate intakes of iron, vitamin D, vitamin C, niacin, riboflavin, and zinc were found in one or more children. The majority of children did not consume adequate amounts of fruit and vegetables, but 94% of the children ate foods on a daily basis that the authors considered to be in the "fatty" and "sugary" food groups. Two other studies collected 3-day food records in groups of children with autism spectrum disorders. Ho and Eaves (21) reported low calcium intake in their sample; however, limited conclusions can be drawn from their data because the overall number of children for whom calcium intake was inadequate was not reported. Information was also lacking on the intake of other micronutrients. Levy and colleagues (22) only reported on the macronutrient content of children's diets which was found to be adequate in almost all the children. A substantial number of children also had a high protein intake. They provided no information on the micronutrient content of the diets.

In a recent study to examine nutritional intake between children with autism spectrum disorders and typically developing children, Herndon and colleagues (8) used a 3-day food record and found that a large number of both children with autism spectrum disorders and typically developing children consumed less than the recommended dietary intakes for several nutrients, including calcium, iron, vitamins D and E, and fiber. Children with autism spectrum disorders were also found to have higher intakes of vitamins B-6 and E and lower intakes of calcium than typically developing children. When the analysis excluded children on gluten-free/casein-free diets, these differences were no longer significant, except for higher vitamin B-6 intake in the children with autism spectrum disorders.

In summary, results of studies of nutrient intake of children with autism spectrum disorders have produced conflicting results, with different studies indicating that the nutrient intakes of children with autism are below, above, or the same as children without autism spectrum disorders. Several studies have compared the intakes of children with autism spectrum disorders to dietary standards, but they did not include a control group, so it was not possible to consider what was unique to autism spectrum disorder. Even more importantly, most studies did not compare children with autism spectrum disorders with and without food selectivity, so it was not possible to determine whether food selectivity placed children at risk.

Various factors, such as changing definitions of autism spectrum disorders and parental dietary restrictions,

such as gluten-free/casein-free diets, can influence current findings such that it is not clear if differences between children with autism spectrum disorders are a result of parental dietary restrictions or to food selectivity. Determining nutritional risk of this population is essential to developing strategies to maximize health. Similarly, examining data for individual children is critical given the high variability within this population.

Autism Spectrum Disorders, Sensory Sensitivity, and Food Selectivity

Various factors can contribute to food selectivity and a number of explanations have been proposed (14). One of these factors relates to sensory sensitivity (also referred to as sensory defensiveness or sensory overresponsivity). Ayres (23) first described sensory defensiveness in the tactile domain (tactile defensiveness) in some children with learning and behavioral disorders. She described tactile defensiveness as an overreaction to certain experiences of touch, often resulting in an observable aversion or negative behavioral response to certain tactile stimuli that most people would find innocuous. For example, children who show tactile defensiveness often have difficulty being cuddled and pull away from touch. It is possible that early tactile sensitivity may contribute to some of the sensory feeding issues, such as difficulty with food textures, seen in children with autism spectrum disorders.

Early descriptive research identified the problem of tactile defensiveness in children with autism spectrum disorders, although they did not use that terminology. Ornitz and Ritvo (24) described behaviors in children with autism spectrum disorders that were characterized by the inability to tolerate certain tactile materials, such as woolen blankets or clothes that came in contact with their skin. In his initial description of children with Asperger syndrome, Hans Asperger (1944, cited in [25]) also described the sensory over- and undersensitivities in this population. Numerous individuals with autism spectrum disorders and their families have identified atypical processing of sensory information (26). Recent research has reported a high prevalence of sensory processing disorders in children across the autism spectrum and at various ages. For example, Leekam and colleagues (27) reported that in a sample of 200 children with autism spectrum disorders, >90% had sensory abnormalities and sensory symptoms and that these occurred in multiple domains. In particular, the proximal domains of touch and smell/taste distinguished autism and nonautism groups. Dunn and colleagues (28) examined the differences between children with Asperger syndrome and typically developing children and found differences on almost all (96%) of the items on the Sensory Profile (29), a parent questionnaire that assesses children's responses to every day sensory activities. Rogers and colleagues (30) reported that both children with autism spectrum disorders and children with Fragile X syndrome had more sensory sensitivity symptoms than children with other developmental disabilities or typically developing children. Ben-Sasson and colleagues (31) examined young children and found that toddlers with autism spectrum disorders showed high frequency of underresponsivity (89%) and overresponsivity (75%), with 67% of the group showing both under- and overresponsivity. Baranek and colleagues (32) reported similar findings in a sample of children ages 2 to 7 years with autism spectrum disorders, although the prevalence was somewhat lower (63% underresponsiveness, 56% overresponsiveness, and 38% both overresponsiveness and underresponsiveness). In a recent meta-analysis, Ben-Sasson and colleagues (33) reviewed results from 14 studies (of 97 potential studies identified), 13 of which included a comparison group of typically developing children and four of which included a comparison group of children with developmental disabilities. The meta-analysis found substantial between-group (autism spectrum disorder:comparison) differences. Mean effect sizes across studies was high and significant, with the majority of 42 individual effect sizes Cohen's $d>.81$, indicating that children with autism spectrum disorders were much more likely to have sensory processing challenges than children without autism spectrum disorders.

Overall, research indicates that sensory issues are extremely common in children with autism spectrum disorders. In fact, some researchers have argued that atypical sensory processing should be one of the diagnostic criteria of autism spectrum disorders (26,34). Sensory issues are seen in very young children, seem to persist, and are seen across a range of severity of autism spectrum disorders.

Effects of Sensory Sensitivity on Eating

Many researchers as well as individuals with autism spectrum disorders have suggested that there is a link between the sensory processing problems that a person experiences and difficulties managing daily life (25,35-37). Eating is one of the areas of daily life activities that may be negatively affected by sensory aversions (1,3,12,29,38,39). Oral defensiveness, which may be a component of tactile defensiveness, is defined as an avoidance of certain textures of food and avoidance of activities using the mouth, such as toothbrushing. Tactile defensiveness and oral defensiveness may be part of a larger problem in modulating sensory input, which can take different forms. Oral overresponsiveness (defensiveness) may result in difficulty with food textures and, therefore, food selectivity. Oral underresponsiveness, in which the child does not appear to adequately perceive sensations, may result in the child overstuffing his or her mouth. Oral-seeking behavior may result in the child putting everything in his or her mouth for the purposes of oral stimulation. Such concerns can be seen in multiple sensory modalities, such as hearing, vision, taste, smell, and touch. Of particular interest in this article is sensory overresponsivity, which can result in a child being a "picky" or selective eater.

Smith and colleagues (40) studied children ages 3 to 10 years with and without tactile defensiveness who did not have autism. Using the Sensory Profile (29), the authors reported that children who showed tactile defensiveness had significant differences in eating habits and food choices as compared to children who scored in the normal range. The children with tactile defensiveness were reported to have a fair to poor appetite, hesitated to eat unfamiliar foods, did not eat at other people's houses, and refused certain foods because of smell and temperature. They also were resistant to eating vegetables, with overall vegetable consumption being half that of children without tactile defensiveness. Children with tactile de-

fensiveness also were reported to gag and/or bite their inner lips and cheeks. Furthermore, these children showed more limited selection of foods and had a pronounced aversion toward textures, smells, and temperatures of food compared to children who did not show tactile defensiveness. This study suggested that food selectivity is not a unique characteristic of autism per se, but may reflect sensory defensiveness.

It has been suggested that sensory sensitivity may lead children with autism spectrum disorders to restrict their intake to food of preferred, tolerable, and manageable textures (1,3,12,17,20). In the studies described here, the texture of foods was consistently identified as a related aspect of food acceptance, suggesting that sensory sensitivity may be a contributing factor to food selectivity. Attwood (25) pointed out that the resistance to eating certain types of food may relate to texture or smell. For example, olfactory overresponsivity may result in a person becoming highly uncomfortable in the school cafeteria, being bothered by the smells of other children's foods. In describing the effects of food textures, Stephen Shore (41), an adult with high-functioning autism, wrote:

> Canned asparagus was intolerable due to its slimy texture, and I didn't eat tomatoes for a year after a cherry tomato had burst in my mouth while I was eating it. The sensory stimulation of having that small piece of fruit explode in my mouth was too much to bear and I was not going to take any chances of that happening again. (p. 44)
>
> Carrots in a green salad and celery in tuna fish salad are still intolerable to me because of the contrast in texture between carrots or celery and salad or tuna fish is too great. However, I enjoy eating celery and baby carrots by themselves. (p. 44)

Such narrative descriptions are supported by the parental reports described previously in this article (12,14).

In addition to the relation between food selectivity and sensory sensitivity, it is also possible that the meal-time behavior problems frequently seen in children with autism spectrum disorders can reflect problems with sensory sensitivity. Leekam and colleagues (27) suggested that particular sensory inputs can cause behavior problems in individuals with autism spectrum disorders who are unable to describe their distress. Of importance is the finding that sensory-based feeding issues create increased stress and negatively affect family meal times and quality of life (1,42-44). Fiese and Schwartz (45) emphasized the importance of meal times because it is the primary daily activity that families share as a group and highlighted the importance of a positive family climate during meal times. Child behavior problems during meal times increase family stress and are disruptive to the family climate.

In summary, research and clinical observations indicate that food selectivity is a major problem in children with autism spectrum disorders. One of the consistent themes in the food selectivity literature relates to food textures. It is possible that sensory sensitivity experienced by many children with autism spectrum disorders may contribute to their difficulty with food texture and resultant food selectivity. Further research is needed to inform appropriate interventions.

Implications for Practice

Evidence to date suggests that food selectivity is a frequently occurring problem in children with autism spectrum disorders and that their unusual eating patterns may be a significant stressor for their families (1,44). Some literature suggests that the diets of children with autism spectrum disorders are nutritionally inadequate, although these findings are mixed. Moreover, research indicates that sensory sensitivity is frequently seen in children with autism spectrum disorders and may explain their difficulty with food textures, smells, and tastes and may contribute to development of food selectivity. Greater insight into the factors that give rise to eating difficulties is important because it allows for the design of more focused interventions.

Feeding problems are complex and often multifactorial. Complex problems are often best addressed using an interdisciplinary approach. In the case of children with autism spectrum disorders who are displaying highly selective eating patterns, interventions might be devised using the input of a registered dietitian (RD), an occupational therapist, and a behavioral psychologist. Children with food selectivity are often first referred to an RD for help with eating and nutrition. Parents are often concerned that their child is not eating a nutritionally adequate diet. Because sensory issues are so common in children with autism spectrum disorders and may influence feeding and family meal times, it is important for RDs to talk with families about children's responses to different types of sensory input, particularly tactile/texture, gustatory, and olfactory input. If it appears that sensory issues are a concern, the child can be referred to an occupational therapist for an evaluation of sensory processing. The occupational therapist will typically interview the parent and can administer a parent questionnaire, such as The Sensory Profile (29), which includes a section on oral sensitivity.

If sensory sensitivity contributes to the child's food selectivity, this can be targeted by multiple approaches. Occupational therapists can help parents understand that the child's seemingly uncooperative behavior and limited food repertoire may actually be the result of sensory sensitivities that can cause great discomfort, and that the child's food refusals may reflect an attempt to cope or compensate for this discomfort (38,41). The RD can identify whether nutritional intake is adequate and can work with parents and occupational therapists to identify alternative foods or alternative food preparation strategies to yield different sensory characteristics that will provide adequate intake of nutrients. Nutritional assessment is essential to the rest of the team members' understanding of how urgent the problem is and what interventions are needed. The initial assessment should include anthropometric measures (ie, height and weight) and comparison to age- and sex-associated reference data to see how well the child is growing. Considerable variation in growth from established reference norms may be related to nutritional inadequacy. The degree of under- or overnutrition should be categorized and monitored.

Use of food records and/or 24-hour diet recalls can help provide information on the total intake profile to guide determination of at-risk nutrients (eg, calories, micro-, and macronutrients). Nutrition support may be needed in

the form of vitamin and mineral supplementation. This may be especially true when the child is a selective eater and is on a specific diet, such as a gluten-free, casein-free diet. The RD can also suggest ways to enrich the diet so that every bite contributes to nutritional adequacy in the child's diet. While working on increasing the acceptable foods, nutrition counseling is critical.

Programs and strategies also can be developed to reduce the child's sensory defensiveness (43). For example, occupational therapy using a sensory integration approach can provide activities that incorporate deep touch pressure and proprioception, which have been reported to decrease sensory defensiveness (46,47). The therapist can also develop social stories (48), sensory stories (49,50), mealtime stories (51), or written charts (1) to help prepare the child to anticipate different foods. The occupational therapist can make suggestions to modify the environment, such as dimming the lights or playing soft music, which can help reduce the child's general arousal levels and facilitate his or her ability to tolerate the sensory stressors presented by food (52). The RD, occupational therapist, and family also can also work with a psychologist to incorporate behavioral approaches to shape the child's acceptance of various food textures (see, for example, [53]).

Collaboration among RDs, occupational therapists, and psychologists can enhance the effectiveness of the dietary intervention. Identifying appropriate foods, modifying the sensory characteristics (ie, texture) of the food, providing appropriate eating utensils, modifying the environment (stimuli), and incorporating supportive behavioral interventions can help facilitate adequate nutrition and reduce family stress at meal times, ultimately enhancing the health of the child.

CONCLUSIONS

Food selectivity appears to be an important issue for many children with autism spectrum disorders. However, the construct of food selectivity has not been operationally defined and there are no "gold standard" measures. Food selectivity in children with autism spectrum disorders can occur for a number of reasons. Sensory sensitivity has been suggested as one possible mechanism to explain, in part, the food selectivity of children with autism spectrum disorders. Further research is needed to examine factors associated with food selectivity including sensory issues, behavior problems, parental preferences, and family meal times. Another important area worthy of future research is a critical examination of the effect of food selectivity on nutritional adequacy, which has implications for child health. Finally, it is critical to examine the outcomes of interventions designed to affect food selectivity in children with autism spectrum disorders and to improve the nutritional status of this population of children.

The criteria for autism spectrum disorders has shifted over time, making it difficult to compare studies and to determine whether subgroups of children with autism spectrum disorders are at greater or lesser risk for food selectivity and whether this problem attenuates or persists over time. Moreover, the relation of food selectivity, special diets, and nutritional adequacy needs to be examined. Additional research is needed in studies that include carefully characterized participants so that the phenomenon of food selectivity across the spectrum of autistic disorders can be understood.

STATEMENT OF POTENTIAL CONFLICT OF INTEREST: No potential conflict of interest was reported by the authors.

FUNDING/SUPPORT: This study was supported in part by a grant from the National Institutes of Health (NIH), National Institute of Health and Child Development (NIH grants R21 HD048989 and HRSA 2 T73MC00056).

ACKNOWLEDGEMENTS: We gratefully acknowledge Melissa Maslin for assistance with the preparation of this manuscript.

References

1. Legge B. *Can't Eat, Won't Eat: Dietary Difficulties and Autistic Spectrum Disorders*. London, UK: Jessica Kingsley Publishers; 2002.
2. Tomchek SD, Dunn W. Sensory processing in children with and without autism: A comparative study using the Short Sensory Profile. *Am J Occup Ther*. 2007;61:190-200.
3. Twachtman-Reilly J, Amaral SC, Zebrowski PP. Addressing feeding disorders in children on the autism spectrum in school-based settings: Physiological and behavioral issues. *Lang Speech Hear Serv Sch*. 2008;39:261-272.
4. Centers for Disease Control. Mental health in the United States: Parental report of diagnosed autism in children aged 4-17 years in the United States, 2003-2004. *MMWR Morb Mortal Wkly Rep*. 2006;55: 481-486.
5. Bowers L. An audit of referrals of children with autistic spectrum disorder to the dietetic service. *J Hum Nutr Diet*. 2002;15:141-144.
6. Cornish E. A balanced approach towards healthy eating in autism. *J Hum Nutr Diet*. 1998;11:501-509.
7. Dovey TM, Staples PA, Gibson EL, Halford JC. Food neophobia and 'picky/fussy' eating in children: A review. *Appetite*. 2008;50:181-193.
8. Herndon AC, DiGuiseppi C, Johnson SL, Leiferman J, Reynolds A. Does nutritional intake differ between children with autism spectrum disorders and children with typical development? *J Autism Dev Disord*. 2009;39:212-222.
9. Lockner DW, Crowe TK, Skipper BJ. Dietary intake and parents' perception of mealtime behaviors in preschool-age children with autism spectrum disorder and in typically developing children. *J Am Diet Assoc*. 2008;108:1360-1363.
10. Raiten DJ, Massaro T. Perspectives on the nutritional ecology of autistic children. *J Autism Dev Disord*. 1986;16:133-143.
11. Schmitt L, Heiss CJ, Campbell EE. A comparison of nutrient intake and eating behaviors of boys with and without autism. *Top Clin Nutr*. 2008;23:23-31.
12. Williams PG, Dalrymple N, Neal J. Eating habits of children with autism. *Pediatr Nurs*. 2000;26:259-264.
13. Klein U, Nowak AJ. Characteristics of patients with autistic disorder (AD) presenting for dental treatment: A survey and chart review. *Spec Care Dentist*. 1999;19:200-207.
14. Whiteley P, Rodgers J, Shattock P. Feeding patterns in autism. *Autism*. 2000;4:207-211.
15. Schreck KA, Williams K, Smith AF. A comparison of eating behaviors between children with and without autism. *J Autism Dev Disord*. 2004;34:433-438.
16. Schreck KA, Williams K. Food preferences and factors influencing food selectivity for children with autism spectrum disorders. *Res Dev Disabil*. 2006;27:353-363.
17. Field D, Garland M, Williams K. Correlates of specific childhood feeding problems. *J Paediatr Child Health*. 2003;39:299-304.
18. Williams KE, Gibbons BG, Schreck KA. Comparing selective eaters with and without developmental disabilities. *J Dev Phys Disabil*. 2005;17:299-309.
19. Dominick KC, Davis NO, Lainhart J, Tager-Flusberg H, Folstein S. Atypical behaviors in children with autism and children with a history of language impairment. *Res Dev Disabil*. 2007;28:145-162.
20. Ahearn WH, Castine T, Nault K, Green G. An assessment of food acceptance in children with autism or pervasive developmental disorder-not otherwise specified. *J Autism Dev Disord*. 2001;31:505-511.

21. Ho HH, Eaves LC. Nutrient intake and obesity in children with autism. *Focus Autism Other Dev Disabl*. 1997;12:187-193.
22. Levy SE, Souders MC, Ittenbach RF, Giarelli E, Mulberg AE, Pinto-Martin JA. Relationship of dietary intake to gastrointestinal symptoms in children with autistic spectrum disorders. *Biol Psychiatry*. 2007;61:492-497.
23. Ayres AJ. Tactile functions. Their relation to hyperactive and perceptual motor behavior. *Am J Occup Ther*. 1964;18:6-11.
24. Ornitz EM, Ritvo ER. The syndrome of autism: A critical review. *Am J Psychiatry*. 1976;133:609-621.
25. Attwood T. *The Complete Guide to Asperger's Syndrome*. London, UK: Jessica Kingsley Publishers; 2006.
26. Chamak B, Bonniau B, Jaunay E, Cohen D. What can we learn about autism from autistic persons? *Psychother Psychosom*. 2008;77:271-279.
27. Leekam SR, Nieto C, Libby SJ, Wing L, Gould J. Describing the sensory abnormalities of children and adults with autism. *J Autism Dev Disord*. 2007;37:894-910.
28. Dunn W, Myles BS, Orr S. Sensory processing issues associated with Asperger syndrome: A preliminary investigation. *Am J Occup Ther*. 2002;56:97-102.
29. Dunn W. *Sensory Profile*. San Antonio, TX: The Psychological Corporation; 1999.
30. Rogers SJ, Hepburn S, Wehner E. Parent reports of sensory symptoms in toddlers with autism and those with other developmental disorders. *J Autism Dev Disord*. 2003;33:631-642.
31. Ben-Sasson A, Cermak SA, Orsmond GI, Tager-Flusberg H, Carter AS, Kadlec MB, Dunn W. Extreme sensory modulation behaviors in toddlers with autism spectrum disorders. *Am J Occup Ther*. 2007;61:584-592.
32. Baranek GT, David FJ, Poe MD, Stone WL, Watson LR. Sensory Experiences Questionnaire: Discriminating sensory features in young children with autism, developmental delays, and typical development. *J Child Psychol Psychiatry*. 2006;47:591-601.
33. Ben-Sasson A, Hen L, Fluss R, Cermak SA, Engel-Yeger B, Gal E. A meta-analysis of sensory modulation symptoms in individuals with autism spectrum disorders. *J Autism Dev Disord*. 2009;39:1-11.
34. Kern JK, Trivedi MH, Grannemann BD, Garver CR, Johnson DG, Andrews AA, Savla JS, Mehta JA, Schroeder JL. Sensory correlations in autism. *Autism*. 2007;11:123-134.
35. Dunn W. The impact of sensory processing abilities on the daily lives of young children and their families: A conceptual model. *Infants Young Child*. 1997;9:23-35.
36. Grandin T. *Thinking in Pictures: And Other Reports from My Life with Autism*. New York, NY: Vintage Books; 1996.
37. Kern JK, Trivedi MH, Garver CR, Grannemann BD, Andrews AA, Savla JS, Johnson DG, Mehta JA, Schroeder JL. The pattern of sensory processing abnormalities in autism. *Autism*. 2006;10:480-494.
38. Ayres AJ. *Sensory Integration and the Child*. Los Angeles, CA: Western Psychological Services; 1979.
39. Dunn W. *Living Sensationally: Understanding Your Senses*. London, UK: Jessica Kingsley Publishers; 2007.
40. Smith AM, Roux S, Naidoo NT, Venter DJ. Food choice of tactile defensive children. *Nutrition*. 2005;21:14-19.
41. Shore SM. *Beyond the Wall: Personal Experiences with Autism and Asperger Syndrome*. Shawnee Mission, KS: Autism Asperger Publishing Co.; 2001.
42. Epstein T, Saltzman-Benaiah J, O'Hare A, Goll JC, Tuck S. Associated features of Asperger syndrome and their relationship to parenting stress. *Child Care Health Dev*. 2008;34:503-511.
43. Ernsperger L, Stegen-Hanson T. *Just Take a Bite: Easy, Effective Answers to Food Aversions and Eating Challenges*. Arlington, TX: Future Horizons; 2004.
44. Groden J, Diller A, Bausman M, Velicer W, Norman G, Cautela J. The development of a stress survey schedule for persons with autism and other developmental disabilities. *J Autism Dev Disord*. 2001;31:207-217.
45. Fiese BH, Schwartz M. Reclaiming the family table: Mealtimes and child health and wellbeing. *Soc Policy Rep*. Vol 22; 2008:3-9,13-20.
46. Kimball J. Sensory integration frame of reference: Postulates regarding change and application to practice. In: Kramer P, Hinojosa J, eds. *Frames of Reference for Pediatric Occupational Therapy*. 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 1999:169-204.
47. Wilbarger JL, Wilbarger PL. Wilbarger approach to treating sensory defensiveness and clinical application of the sensory diet. Sections in Alternative and complementary programs for intervention. In: Bundy AC, Lane S, Murray EA, Fisher AG, eds. *Sensory Integration: Theory and Practice*. 2nd ed. Philadelphia, PA: F.A. Davis; 2002:335-341.
48. Gray C. *The New Social Story Book: Illustrated Edition*. 2nd ed. Arlington, TX: Future Horizons; 2000.
49. Marr D, Mika H, Miraglia J, Roerig M, Sinnott R. The effect of sensory stories on targeted behaviors in preschool children with autism. *Phys Occup Ther Pediatr*. 2007;27:63-79.
50. Marr D, Nackley VL. *Sensory Stories (A Complete Set of 30 Stories).* Framingham, MA: Therapro; 2007.
51. Tucker MT, Neifert M. *Mealtime Stories: A Guide for Feeding Therapists*. 2nd ed. Seattle, WA: Mealtime Stories; 2008.
52. Williams MS, Shellenberger S. *How Does Your Engine Run? Leader's Guide to the Alert Program for Self Regulation, Revised Edition*. Albuquerque, NM: TherapyWorks, Inc; 1996.
53. Paul C, Williams KE, Riegel K, Gibbons B. Combining repeated taste exposure and escape prevention: An intervention for the treatment of extreme food selectivity. *Appetite*. 2007;49:708-711.