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ORIGINAL ARTICLE

Psychological, Health, and Demographic Correlates of Atypical Eating Behaviors in Children with Autism

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Abstract

Potential psychological, health, and demographic correlates of atypical eating behaviors in children with autism were analyzed in the largest sample with the broadest range of independent variables to date. Eating behaviors were assessed in 1112 children with autism 1–17 years of age using the Checklist for Autism Spectrum Disorder (CASD), a standardized parent interview conducted by licensed psychologists. Independent variables were demographics (age, IQ, sex, race, and parent occupation), 29 CASD autism symptom scores (e.g., distress with change and sensory hypersensitivity), psychotropic medication use, and maternal ratings on the Pediatric Behavior Scale assessing psychopathology (e.g., behavior problems, ADHD, anxiety, and depression), appetite, weight, gastrointestinal problems, and other health problems. Atypical eating behaviors were found in 70.5% of children and were positively related to only four variables: age (most common at ages 1–3), increasing autism severity (total number of autism symptoms present), poor appetite, and constipation. Given the high prevalence of atypical eating behaviors in autism and their presence at a very young age, primary care and early intervention providers should be alert to these problems and if present, consider the possibility of autism and a referral for a diagnostic evaluation so that children with autism can access behavioral intervention shown to be effective in treating autism in toddlers and young preschoolers, as well as in treating the atypical eating behaviors.

Keywords Atypical eating behaviors · Limited food preferences · Autism

Atypical eating behaviors have been recognized as common in autism since autism was first identified as a disorder (Kanner 1943). The most frequent atypical eating behavior in autism is limited food preferences (Beighley et al. 2013; Bicer and Alsaffar 2013;

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Postorino et al. 2015), followed by hypersensitivity to food textures, then other peculiar patterns, such as eating only one brand of food, pocketing food without swallowing, and pica (Matson et al. 2009; Mayes et al. 2018). Atypical eating behaviors are far more common in autism than in other developmental disabilities (Beighley et al. 2013; Matson et al. 2009; Valicenti-McDermott et al. 2006), ADHD (Mayes et al. 2018), and typical development (Bandini et al. 2017; Beighley et al. 2013; Castro et al. 2016; Curtin et al. 2015; Emond et al. 2010; Kuschner et al. 2015; Lockner et al. 2008; Martins et al. 2008; Matson et al. 2009; Schreck et al. 2004; Valicenti-McDermott et al. 2006; Zimmer et al. 2012). Across seven studies, the median prevalence of limited food preferences in children with autism is 63% (Bicer and Alsaffar 2013; Dominick et al. 2007; Lockner et al. 2008; Mayes et al. 2018; Schreck et al. 2004; Valicenti-McDermott et al. 2006; Williams et al. 2000).

Food Sensory Sensitivities

Grain products (e.g., bread, cereal, and pasta) and/or chicken (usually nuggets) were preferred foods for 92% of children with autism who had limited food preferences (Mayes et al. 2018). A common feature of these foods is that they are uniform in texture, relatively bland in taste, and neutral in color, suggesting that children with autism may be sensitive to these sensory aspects of food which may influence their preferences. Similarly, some mothers of 12 children with autism who had limited food repertoires and other feeding challenges noted sensory aversions related to the texture, sight, and smell of foods (Rogers et al. 2012). Schmidt et al. (2008) reported that 20 boys with autism (7–10 years) had less varied diets than controls and based food choices on texture to a greater degree than typical boys. Parent interview data for 79 children with autism who had food selectivity (Postorino et al. 2015) indicated that all had one or more food sensory factor linked to food selectivity, most often texture (68%), followed by taste (53%), color (20%), form (16%), brand/packaging (13%), smell (10%), and temperature (1%). Matson and colleagues (Matson et al. 2009) found that 82% of 72 children with autism and 65% of 40 children with PDD-NOS preferred foods of a certain texture or smell compared to 11% with typical development. In contrast, Schreck and Williams (2006) found that only 6% of parents of 138 children with autism attributed their children's food selectivity to texture, and 48% reported rejection based on how food was presented, including form, brand, packaging, arrangement on the plate, and proximity to other foods.

Nonfood Sensory Sensitivities

Some authors hypothesize that nonfood sensory hypersensitivities may lead to atypical eating behaviors in autism. Three studies found a significant relationship between atypical eating behaviors in children with autism and sensory processing abnormalities not specifically related to food. In a study of 52 children with autism 3–8 years of age (Suarez et al. 2014), severe food selectivity was associated with the total score on a scale assessing tactile, auditory, visual, and vestibular processing problems. In a study of 141 children with autism 3–9 years of age (Suarez and Nelson 2012), an increase in food selectivity was associated with tactile defensiveness, but not with visual, auditory,

and vestibular over-responsiveness when all variables were entered in regression analysis. In 95 children with autism 3–10 years of age, the number of eating problems (which included problems other than limited food preferences, such as eating only with one parent and difficulty transitioning to solids) was greater in children with tactile, visual/auditory, and taste/smell sensitivities than in children without sensitivities (Nadon et al. 2011). In contrast, Martins et al. (2008) studied 41 children with autism 2–12 years of age and found that the Child Autism Rating Scale item assessing unusual sensory exploration and reactivity (e.g., "touching, smelling, or tasting objects or people") was not associated with avoidance of particular categories or textures of food. However, this study was unique from others in that it measured sensory-seeking behavior rather than behaviors associated with sensory hypersensitivity and avoidance.

General population studies lend support to a possible relationship between selective eating and sensory problems. Zucker et al. (2015) found that selective eating was associated with enhanced sensitivity to food texture, smell, visual cues, and motion in 917 children 2–6 years of age. In a study of 95 children 5–10 years (Farrow and Coulthard 2012), selective eating was associated with tactile, but not auditory or visual sensitivities. In 158 children and adolescents ages 8–17 with anxiety and obsessive-compulsive disorder, a sensory sensitivity score across six domains (touch, small, audition, vision, body position, and movement) was associated with selective eating independent of anxiety symptomatology (Zickgraf and Elkins 2018). Sensory sensitivity to both taste and non-taste sensory modalities has also been related to selective eating in adult samples, suggesting that multimodal sensory over-sensitivity may be a significant correlate of selective eating throughout development (Kauer et al. 2015; Wildes et al. 2012; Zickgraf and Elkins 2018; Zickgraf et al. 2016).

Desire to Maintain Sameness

Another hypothesis is that desire to maintain sameness and resistance to change may contribute to limited food preferences in autism. In a study of 12 children with autism who had limited food preferences and other feeding challenges (Rogers et al. 2012), some mothers noted that their child only ate certain brands of foods and refused foods if presented differently. Scores on the Child Autism Rating Scale item measuring resistance to change (e.g., change in routine or activity) were associated with increased avoidance of new foods, food avoidance behaviors, and ritualistic eating behaviors in 41 children with autism 2–12 years of age (Martins et al. 2008). Suarez et al. (2014) reported that when scores on an item measuring tactile, visual, auditory, and vestibular sensory processing problems and a single item assessing restricted and repetitive behaviors were entered together in regression analysis, only the sensory processing problem score was a significant predictor of severe food selectivity in 52 children with autism 3–8 years of age, even though both scores were significant in the univariate analyses.

Autism Instrument Symptom Scores

Results regarding the relationship between total autism symptom scores and atypical eating behaviors are contradictory. Aponte and Romanczyk (2016) found a positive

relationship between the total score on an autism parent rating scale (PDD Behavior Inventory) and the score on a scale assessing limited variety of intake and food refusal completed by parents of 38 children with autism 3–11 years of age. Postorino et al. (2015) reported higher rates of autism symptoms in 79 children with autism and food selectivity compared to 79 with autism and no food selectivity. In contrast, the relationship was nonsignificant between the Gilliam Autism Rating Scale score completed by parents and number of preferred foods reported by parents of 138 children with autism 4–12 years of age (Schreck and Williams 2006). Further, the Child Autism Rating Scale (CARS) autism severity item score was not related to food avoidance and picky eating in 41 children with autism 2–12 years of age (Martins et al. 2008).

Behavior Problems and Psychopathology

A study of 100 children with autism (Williams et al. 2000) found that children who were described by their parents as "upset a great deal of the time" were more likely to be picky eaters than children who were easy-going. Similarly, studies of children with autism demonstrated that limited food preferences were associated with child mealtime behavior problems in 53 children (Curtin et al. 2015), tantrums in 67 children (Dominick et al. 2007), and higher rating scale scores on both externalizing and internalizing problem scales in 158 children (Postorino et al. 2015). Likewise, in a sample of 917 community children 2–6 years of age (Zucker et al. 2015) selective eating was associated with behavior problems outside the home and elevated symptoms of psychopathology, including anxiety, depression, and ADHD (autism was not assessed). However, anxiety was not significantly related to picky eating in 158 children and adolescents with anxiety disorders when sensory hypersensitivity was controlled (Zickgraf and Elkins 2018). Results from studies showing a relationship between atypical eating and behavior problems do not imply uni- or bidirectional effects, nor do they indicate if the relationship is explained by an association with a third variable. Interestingly, ADHD ratings were not significantly related to eating problems in 95 children with autism when multiple variables were entered in regression analysis (Nadon et al. 2011), in contrast to the significant univariate finding reported by Zucker et al. (2015) for community children.

Weight

Body mass index was not associated with food selectivity in 158 children with autism (Postorino et al. 2015). General population studies yield conflicting findings. Some studies report a nonsignificant relationship between limited food preferences and reduced weight (van der Horst et al. 2016) and growth (Wright et al. 2007) and others a significant relationship (Dubois et al. 2007; Equit et al. 2013; Zucker et al. 2015).

Gastrointestinal Problems

Research findings on a relationship between gastrointestinal (GI) problems and food selectivity are also inconsistent. The majority of studies show food selectivity in autism

is not related to GI problems (Gorrindo et al. 2012; Postorino et al. 2015; Suarez and Nelson 2012), although one study (Valicenti-McDermott et al. 2006) found an association in children with autism but not in children with other developmental disabilities or typical children. Other studies of typical children reported a bidirectional relationship between selective eating and constipation (Tharner et al. 2015) and that children with constipation were more likely to be picky eaters than children without constipation (Chang et al. 2013).

Psychotropic Medication

The most commonly prescribed psychoactive medications for children with autism are psychostimulants (most often methylphenidate), antipsychotics (most often risperidone), and SSRIs (Murray et al. 2014; Oswald and Sonenklar 2007). Most children with autism meet criteria for ADHD (Mayes et al. 2012a) and experience ADHD symptom reduction on stimulants (Cortese et al. 2012). The most frequent stimulant side effect in autism is reduced appetite (Cortese et al. 2012). Weight gain is the most common side effect of risperidone, which has been shown to be effective in reducing behavior problems, aggression, tantrums, self-injurious behavior, and hyperactivity in children with autism in controlled 2- to 6-month trials (McCracken et al. 2002; Nagaraj et al. 2006; Pandina et al. 2007). As reported in a review by West et al. (2009), fluoxetine (an SSRI) decreased global autism severity ratings in three studies with no reported side effects related to appetite or weight. A review by Moore et al. (2004) indicated that SSRIs reduced functional impairments in autism (e.g., repetitive thoughts and behaviors, impaired social skills, irritability, and aggression) and only 6% of children experienced a change in appetite (most often a decrease) and 2% weight gain. In contrast to studies documenting the effect of medication on appetite, research on the relationship between atypical eating behaviors (e.g., limited food preferences) and medication in children with autism has not been investigated.

Demographics

IQ and Ability Test Scores In two studies of children with autism and a broad IQ range (intellectually disabled to above average), IQ was not related to atypical eating behaviors in 67 children (Dominick et al. 2007) and in 50 children (Valicenti-McDermott et al. 2006). Further, atypical eating behaviors were not associated with nonverbal and verbal IQ and language scores (Dominick et al. 2007). Likewise, Nadon et al. (2011) reported that intellectual disability was not associated with eating problems in 95 children with autism when multiple variables were considered together in regression analysis. In contrast, Postorino et al. (2015) studied children with autism who had Leiter-R Brief IQs spanning a broad range (below to above average) and reported that the 79 children with food selectivity had significantly lower nonverbal IQs (*M* 87) than the 79 children without food selectivity (*M* 99). Differences between the two groups were nonsignificant on all of the Vineland Adaptive Behavior subscales.

Age In a cross-sectional study over a broad age range (2–18 years), a decrease in food selectivity with age was found in 269 children with autism (Beighley et al. 2013).

However, a cross-sectional study of 141 children with autism with a more restricted age range (3–9 years) reported that food selectivity was not significantly related to age (Suarez and Nelson 2012), and Nadon et al. (2011) reported that age was not associated with eating problems in children 3–10 years with autism when other variables were controlled in regression analysis. Two longitudinal studies demonstrated no change in food selectivity over 20 months (mean age 8 years at follow-up) in 52 children with autism (Suarez et al. 2014) and no change in food repertoire but a decrease in food refusal from a mean 7 to 13 years in 18 children with autism (Bandini et al. 2017).

Sex Sex was not significantly related to eating problems (which included picky eating, oral-motor difficulties, mealtime behavior problems, and inadequate intake) in 95 children with autism when other variables were controlled, and only sensory sensitivity emerged as a significant predictor of eating problems (Nadon et al. 2011). General population studies of 2371 children 1–4 years of age (van der Horst et al. 2016) and 1498 children 2–4 years (Dubois et al. 2007) each demonstrated a nonsignificant relationship between sex and picky eating. A review of general population studies from infancy through middle childhood (Cardona Cano et al. 2015a) indicated that most studies reported a nonsignificant relationship between sex and picky eating, with the exception of one study showing that children whose picky eating persisted from 1to 6 years of age were more likely to be boys (Cardona Cano et al. 2015b).

SES The relationship between SES and atypical eating behaviors has not been studied in autism. A general population study of 2371 children 1–4 years of age found that picky eating was not related to parent income (van der Horst et al. 2016). However, other large general population studies reported greater picky eating in children in families with low (versus sufficient) incomes (Dubois et al. 2007) and that SES was lower in children with picky eating that persisted from 1to 6 years of age than in children who were never picky eaters (Cardona Cano et al. 2015b).

Race The relationship between race and atypical eating behaviors has also not been investigated in autism. A general population study of 2371 children 1–4 years of age (van der Horst et al. 2016) showed that very picky eaters were more likely to be white (46%) or Hispanic (31%) than black (16%).

Purpose

All previous research on correlates of atypical eating behaviors in autism is based on relatively small sample sizes, limiting the ability to discern significant relationships if they exist or possibly skewing results if the small samples are not representative of children with autism. Our sample of children with autism is far larger than previous studies and covers a broad age range (1–17 years) and IQ range (intellectual disability to gifted), permitting a comprehensive assessment of age and IQ relationships not possible with previous studies using restricted ranges. Our study uses a validated and standardized parent clinical interview measure individually administered by psychologists to assess the presence of atypical eating behaviors, unlike most prior studies relying on surveys completed by parents independently or during phone interviews.

Most previous studies focused on only a small number of variables using univariate analyses and did not simultaneously analyze a broad spectrum of variables to determine the unique and independent contribution of each variable. Our study employs both univariate and multivariate analytic approaches to better clarify the relationship between atypical eating behaviors and independent variables.

Method

Sample

The sample comprised 1112 children with autism 1 to 17 years ($M = 6.4$ years, $SD = 3.3$). Full scale IQs ranged from 9 to 146 ($M = 91.0$, $SD = 25.6$). In all, 71.2% had an IQ $\geq$ 80, 81.8% were male, 89.4% were white, 34.6% had a parent with a professional or managerial occupation, and 31.6% were treated with psychotropic medication. All children underwent a comprehensive diagnostic evaluation by a licensed PhD psychologist. The evaluation included a semi-structured diagnostic interview with the parents using the Checklist for Autism Spectrum Disorder (CASD, Mayes 2012), questionnaires and rating scales completed by parents and teachers (Pediatric Behavior Scale, PBS, Lindgren and Koeppl 1987), review of educational and medical records, administration of psychological tests (IQ, achievement, attention, and neuropsychological), and clinical observations during psychological testing. All children had a clinical diagnosis of autism and a score in the autism range on the CASD.

Instruments

The CASD is a 30-item a semi-structured diagnostic measure scored by a clinician based on a parent interview and information from other sources (e.g., teacher report and clinical observations). The CASD was normed and standardized on 2469 children (1–18 years of age) with autism, other clinical disorders, and typical development (Mayes 2012). Children with autism (both with normal and below normal intelligence) earn CASD total scores at or above the autism cutoff of 15 (Mayes and Calhoun 1999, 2004, 2011). In the standardization study, the mean score for children with autism was 22, whereas the range of scores for children with ADHD, oppositional defiant disorder, anxiety disorder, intellectual disability, and language disorder was 2–7 and the mean for typical children was 1 (Mayes 2012). The CASD completed by psychologists differentiated children with and without autism with 99.5% accuracy (Mayes 2012). Other studies demonstrate the CASD distinguishes children with autism from children with apraxia of speech (Tierney et al. 2015), reactive attachment disorder (Mayes et al. 2016), and ADHD (Mayes et al. 2012a). Agreement on autism diagnoses made using the CASD and other established measures (Childhood Autism Rating Scale, Gilliam Asperger's Disorder Scale, and Autism Diagnostic Interview-Revised) ranges from 93% to 98% (Mayes et al. 2009; Murray et al. 2011).

The PBS rated by parents and teachers measures multiple areas of psychopathology (e.g., oppositional defiant disorder, ADHD, anxiety, depression, and social, somatic, and developmental problems). The PBS has been used in several studies to diagnose and measure psychological problems and differentiate diagnostic groups (e.g., Conrad

et al. 2010; Mattison and Mayes 2012; Mayes et al. 2011; Mayes et al. 2012b; Nichols et al. 2000; Wolraich et al. 1994). The PBS corresponds well with established measures of ADHD, anxiety, and depression (Bixler et al. 2009; Mayes et al. 2014).

Dependent Variable

The dependent variable was "atypical eating behaviors," which is a CASD item scored as present or absent. The item has five sub-items: (1) "very picky eater, limited food preferences, insists on eating only a few foods," (2) "hypersensitivity to textures (e.g., lumps in food)," (3) "retains food in mouth without swallowing," (4) "eats inedible substances," and (5) "other peculiar eating patterns (e.g., eats only one brand, color, or shape of food").

Independent Variables

Independent variables were (1) demographics (IQ, age, sex, race, and parent occupation), (2) scores on the remaining 29 CASD items assessing autism symptoms including problems with social interaction, perseveration (e.g., obsessive preoccupations, stereotyped and repetitive play, distress with change, desire to maintain sameness, and stereotypies), somatosensory disturbance (e.g., auditory and tactile hypersensitivities, high pain tolerance, abnormal sensory inspection, and sensory seeking behavior), communication impairment, atypical speech patterns, splinter skills, emotional overreactivity, tantrums, limited empathy, unusual fears, selective attention, and poor safety awareness, (3) total CASD autism symptom score minus atypical eating behaviors (possible range for children with autism 15–29), (4) category of psychotropic medication prescribed in our sample (i.e., stimulant, antipsychotic, anticonvulsant, alpha antagonist, SSRI, non-SSRI antidepressant, anxiolytic, lithium, atomoxetine, and lithium), and (5) PBS parent scores assessing: (a) behavior problems (e.g., oppositional behavior, tantrums, aggression, irritability, and conduct problems), ADHD, anxiety, depression, and social problems, (b) poor appetite, underweight, over-eating, and overweight, (c) GI problems (constipation, diarrhea, nausea or vomiting, and stomachaches), and (d) other health problems (a single composite score reflecting headaches, body aches and pains, feeling sick, dizziness, fever, skin problems, asthma, seizures, and fatigue).

Data Analyses

Differences between children with and without atypical eating behaviors on the continuous independent variables (e.g., age and total autism symptom score) were determined using *t*-tests and Cohen's *d*. Chi-square, Fisher's exact test, and phi coefficients were used to investigate differences between children with and without atypical eating behaviors on binary variables (e.g., sex and medication). The reported *p*-values for the 29 CASD symptom scores, the six PBS subscale behavior problem and psychopathology scores, the 12 PBS behavior problem and psychopathology item scores, and the nine PBS medical problem item scores have a Bonferroni correction for the number of comparisons made. Variables that differed significantly ($p < .01$) between children with and without atypical eating behaviors in the univariate analyses were entered in stepwise binomial logistic regression analysis to determine the

variables that contributed significantly and uniquely to predicting the presence or absence of atypical eating behaviors. Because psychologists completing the CASD were not required to indicate which specific sub-items were present when the atypical eating behavior item was scored as present, sub-item scores were available for only 144 children. The probability of co-occurrence of types of atypical eating behavior was calculated for these children.

Results

Demographics

Atypical eating behaviors were found in 70.5% of the 1112 children with autism. Demographic differences between children with and without atypical eating behaviors were nonsignificant (Table 1), with one exception: children with atypical eating behaviors were younger than children without atypical eating behaviors. Percentages of children with atypical eating behaviors were highest at ages 1, 2 and 3 years (80.0%, 80.9%, and 78.3%), compared to all other age groups (mean 68.3%), $\chi^2 = 10.3$, $p = .001$, but the effect size was small ($\phi = .10$).

Autism Severity and Symptoms

Total CASD scores (excluding the atypical eating behaviors item) were higher in children with atypical eating behaviors ($M = 21.6$, $SD = 3.4$) than in children without atypical eating behaviors ($M = 20.4$, $SD = 2.9$), $t = 6.0$, $p < .0001$, $d = 0.4$. None of the CASD Problems with Social Interaction, Perseveration (e.g., desire to maintain sameness), Mood and Behavior Problems, or Problems with Attention and Safety subscale item frequencies differed significantly ($p > .01$) between children with and without atypical eating behaviors (Table 2). One of the Atypical Communication and Development subscale items (language regression between 1 and 2 years of age) and one of the Somatosensory Disturbance subscale items (tactile defensiveness) were more common in children with than without atypical eating behaviors, but the effect sizes for both were small ($\phi = .10$). Effect sizes for the remaining 27 CASD autism symptoms were even smaller. For children for whom the type of atypical eating pattern was

Table 1 Demographic differences in children with ($n = 784$) and without ($n = 328$) atypical eating behaviors

% of children with atypical eating behaviors			χ^2	p	ϕ
70.5% Male	70.3% Female		0.0	.94	.00
69.9% White	75.4% Nonwhite		1.5	.22	.04
71.9% Professional	69.7% Nonprofessional		0.6	.44	.02
69.1% IQ < 80	71.1% IQ ≥ 80		0.4	.50	.02
	Atypical eating behaviors				
	Yes	No	t	p	d
Age Mean (*SD*)	6.2 (3.3)	7.0 (3.5)	3.9	.0001	0.26
IQ Mean (*SD*)	90.6 (25.7)	92.1 (25.3)	0.9	.370	0.06

Table 2 Percent of children with and without Checklist for Autism Spectrum Disorder (CASD) symptoms for children with ($n = 784$) and without ($n = 328$) atypical eating behaviors

	Atypical eating behaviors			
	Yes	No	χ^2	p
Problems with Social Interaction				
Social isolation, difficulty making friends	96.6%	96.3%	0.0	1.0
Limited reciprocal interaction (e.g., poor eye contact)	84.9	81.1	2.4	1.0
Self-absorbed, in own world	84.4	82.0	1.0	1.0
Socially indiscriminate, problems with personal space	77.9	77.4	0.0	1.0
Problems with social skills	97.8	98.8	1.1	1.0
Perseveration				
Obsessions (e.g., restricted interests and fixations)	95.4	95.7	0.1	1.0
Repetitive play (e.g., lining up toys)	76.0	71.6	2.3	1.0
Distress with change, desire to maintain sameness	94.3	92.7	1.0	1.0
Stereotypies (e.g., hand flapping, toe walking)	77.4	74.7	1.0	1.0
Somatosensory Disturbance				
Crave movement (e.g., climbing, jumping, spinning)	59.8	48.8	11.5	.03
Unresponsive to verbal input (e.g., to name)	87.5	79.3	11.9	.03
Hypersensitive to sounds, smell, or light	79.3	75.0	2.5	1.0
Distress with commotion or crowds	47.1	46.6	0.0	1.0
Fascination with repetitive movements (e.g., fans)	36.6	29.3	5.5	.55
Abnormal sensory inspection (e.g., mouthing, smelling)	59.9	49.1	11.1	.03
Tactile defensiveness	75.1	64.6	12.6	.01
High pain tolerance	48.9	47.3	0.2	1.0
Sleep disturbance	68.2	60.1	6.9	.26
Atypical Communication and Development				
Language regression or slowing after 1 year	29.3	18.3	14.6	.004
Normal motor and delayed speech milestones	70.8	63.4	5.8	.46
Communication impairment	87.6	88.1	0.1	1.0
Atypical, repetitive vocalizations or speech	88.4	85.4	1.9	1.0
Special abilities (e.g., memory, visual-mechanical)	83.4	79.3	2.7	1.0
Mood and Behavior Problems				
Overreactive, meltdowns, aggression	92.6	90.2	1.7	1.0
Moody, emotionally labile	76.5	73.2	1.4	1.0
Problems with empathy or expressing emotions	64.7	60.7	1.6	1.0
Unusual fears	42.5	37.8	2.1	1.0
Problems with Attention and Safety				
Selective attention	98.7	98.2	0.5	1.0
Poor safety awareness	76.1	72.3	1.9	1.0

specified ($n = 144$), the two most common types were limited food preferences (86.8%) and sensitivity to food texture (47.6%), which were independent of each other ($\chi^2 = 0.3$, $p = .61$). For children with limited food preferences, 51.6% did not have

hypersensitivity to food textures. The majority of children (59.6%) had more than one type of atypical eating behavior.

Behavior Problems and Psychopathology

Children with and without atypical eating behaviors did not differ significantly from each other on any of the behavior problem or psychopathology scores (Table 3).

Health Problems

Poor appetite and constipation were reported significantly more often ($p < .01$) in children with than without atypical eating behaviors (Table 4) with moderate effect sizes ($d = 0.6$ and 0.3, respectively). Poor appetite was often or very often a problem in 30.9% of children with atypical eating behaviors in contrast to 10.0% of children without atypical eating behaviors. Constipation was often or very often a problem in 16.7% of children with atypical eating behaviors, versus 8.6% of children without atypical eating behaviors. Children with and without atypical eating behaviors did not differ on any other GI problem or on the other health problems composite score.

Table 3 Mean Pediatric Behavior Scale (PBS) psychopathology scores[a] for children with ($n = 784$) and without ($n = 328$) atypical eating behaviors

	Atypical eating behaviors			
	Yes Mean (*SD*)	No Mean (*SD*)	*t*	*p*
PBS mean subscale score				
Oppositional behavior	1.4 (0.8)	1.5 (0.7)	0.8	1.0
Conduct problems	0.6 (0.6)	0.6 (0.6)	0.6	1.0
ADHD	1.8 (0.7)	1.8 (0.7)	1.0	1.0
Anxiety	1.0 (0.7)	0.9 (0.7)	1.3	1.0
Depression	0.6 (0.6)	0.6 (0.6)	1.1	1.0
Social problems	1.2 (0.7)	1.2 (0.8)	0.6	1.0
PBS mean item score				
Disobedient	1.5 (0.9)	1.6 (0.8)	0.0	1.0
Argues	1.4 (1.0)	1.6 (0.9)	2.2	.31
Uncooperative	1.4 (0.9)	1.3 (0.8)	0.9	1.0
Defiant	1.4 (1.0)	1.4 (1.0)	0.9	1.0
Aggressive	1.0 (1.0)	0.9 (1.0)	1.4	1.0
Explosive	1.1 (1.1)	1.1 (1.0)	0.0	1.0
Irritable, angry	1.7 (1.0)	1.7 (1.0)	0.1	1.0
Overreacts	1.6 (1.1)	1.6 (1.1)	0.7	1.0
Temper tantrums	1.6 (1.0)	1.5 (1.0)	1.4	1.0
Self-injurious behavior	0.6 (1.0)	0.5 (0.8)	1.6	1.0
Fearful, anxious, worries	1.2 (1.1)	1.2 (1.0)	0.2	1.0
Sad	0.6 (0.8)	0.6 (0.8)	0.2	1.0

[a] 0 = almost never or not at all, 1 = sometimes, 2 = often, and 3 = very often a problem

Table 4 Mean Pediatric Behavior Scale (PBS) health problem item scores[1] for children with ($n = 784$) and without ($n = 328$) atypical eating behaviors

	Atypical eating behaviors			
	Yes Mean (*SD*)	No Mean (*SD*)	*t*	*p*
Poor appetite	1.0 (1.2)	0.4 (0.8)	10.1	<.0001
Underweight	0.4 (0.8)	0.2 (0.7)	2.8	.04
Eats too much	0.4 (0.8)	0.5 (0.9)	2.0	.40
Overweight	0.2 (0.7)	0.3 (0.8)	1.3	1.0
Nausea or vomiting	0.2 (0.5)	0.1 (0.4)	1.3	1.0
Stomachaches	0.4 (0.7)	0.4 (0.7)	1.1	1.0
Constipation	0.5 (0.9)	0.3 (0.7)	4.2	.0003
Diarrhea	0.3 (0.6)	0.2 (0.6)	1.5	1.0
Bowel accidents/soils	0.7 (1.1)	0.6 (1.0)	1.5	1.0
Other health problems[2]	0.3 (0.3)	0.3 (0.3)	0.0	1.0

[1] 0 = almost never or not at all, 1 = sometimes, 2 = often, and 3 = very often a problem

[2] Mean composite score on other health problems (headaches, aches and pains, complains of feeling sick, dizzy, fevers, skin problems, asthma, seizures, and fatigue)

Psychotropic Medication

In the total sample of 1112 children, 351 (31.6%) were currently treated with a psychotropic medication (Table 5). Among treated children, 56.8% were prescribed a stimulant (most often methylphenidate), 37.8% an antipsychotic (most often risperidone), 22.3% an SSRI (most often sertraline of fluoxetine), 17.3% an alpha 2 agonist (clonidine or guanfacine),

Table 5 Atypical Eating Behaviors Percentages for children treated ($n = 351$) or not treated ($n = 761$) with psychotropic medication

Medication type	% on each medication type[1]	% with atypical eating behavior			
		Medicated	Not medicated	χ^2	*p*
Any psychotropic	31.6%	67.2%	72.0%	2.6	.10
Stimulant	56.8%	67.0%	71.3%	2.0	.24
Antipsychotic	37.8%	63.8%	71.4%	3.2	.08
SSRI	22.3%	77.3%	70.1%	1.8	.18
Alph-2 agonist	17.3%	66.5%	70.8%	0.8	.39
Anticonvulsant	14.3%	62.5%	70.9%	1.6	.21
Atomoxetine	7.7%	65.4%	70.7%	0.3	.56
Antidepressant	3.0%	60.0%	70.7%	0.5	.49
Antianxiety	2.4%	62.5%	70.6%	0.3	.70
Lithium	1.5%	80.0%	70.5%	0.2	1.0

[1] % for each type of medication listed (with or without another psychotropic medication) among children treated with medication. Note: 44.0% of children on medication were treated with two or more types of medication and some were treated with two or more different brands within a type

14.3% an anticonvulsant (usually prescribed to treat epilepsy and most often lamotrigine), 7.7% atomoxetine, 3.0% a nonSSRI antidepressant (most often bupropion), 2.4% an anxiolytic (most often buspirone), and 1.5% lithium. Percentages of children with versus without atypical eating behaviors did not differ significantly for children treated versus not treated with any of these types of medications. Most children (56.0%) were treated with only one type of medication, 29.5% with two types, and 14.6% with three or four types. For the two most commonly prescribed medication types (stimulants and antipsychotics), the atypical eating behavior frequencies did not differ between the 130 children who were treated with a stimulant without an antipsychotic, the 66 with an antipsychotic without a stimulant, the 61 children treated with both medication types, and the 761 children not treated with any psychotropic medication, with atypical eating behavior percentages of 67.7%, 62.1%, 65.6%, and 72.0%, respectively ($\chi^2 = 4.3$, $p = .24$).

Multivariate Analysis

The variables significant in univariate analyses were entered in stepwise regression analysis. Age, CASD total score excluding atypical eating behaviors, poor appetite, and constipation together classified children with and without atypical eating behaviors with 70.2% accuracy ($\chi^2 = 120.0$, $p < .0001$). The remaining variables significant in univariate analyses (tactile defensiveness and language regression at 1–2 years) did not contribute significantly more to predicting the presence or absence of atypical eating behaviors.

Discussion

Atypical eating behaviors (most often limited food preferences, followed by oral sensitivity to food texture) were found in 70.5% of the 1112 children with autism. Among demographic variables, children with and without atypical eating behaviors differed only in age. Children ages 1–3 had a higher frequency of atypical eating behaviors than older children, but the effect size was relatively small and both 1- to 3-year-olds and older children had high frequencies of atypical eating behaviors (80% and 68%, respectively). Our findings are consistent with a study of children with autism similar to our age range (2–18 years) showing that food selectivity decreased with age (Beighley et al. 2013), whereas studies with a more restricted age range (3–10 years) found a nonsignificant relationship between age and limited food preferences (Nadon et al. 2011; Suarez and Nelson 2012).

In typical children, the prevalence of picky eating peaks at age 2, with approximately 50% of toddlers described as picky eaters by their parents (Cardona Cano et al. 2015b; Carruth et al. 2004). After age 2, picky eating decreases and the incidence of picky eating after age 5 is very low (Mascola et al. 2010). Although the prevalence of picky eating in toddlers in general population samples is relatively high, the prevalence in our sample with autism was notably higher. One of the important implications of this finding is that atypical eating behaviors are apparent at a very young age in children with autism and should signal primary care providers to look for other symptoms of autism and, if found, consider a referral for a diagnostic evaluation so that the child can access early intervention services proven to be effective for toddlers with autism (Dawson et al. 2010; Harris and Handleman 2000).

All other demographic variables in our study (race, parent occupation, sex, and IQ) were not related to atypical eating behaviors. Race and parent occupation had not been previously studied in autism. General population studies are inconsistent regarding SES, as noted in our Introduction. Our nonsignificant finding for sex is consistent with another autism study (Nadon et al. 2011) and two general population studies (Dubois et al. 2007; van der Horst et al. 2016). Similar to our results, the majority of studies reviewed in our Introduction found a nonsignificant relationship with IQ in autism.

Children with atypical eating behaviors had a higher mean CASD score (21.6) than children without atypical eating behaviors (20.4). However, the effect size was relatively small, with groups differing by the equivalent of only a single symptom, and both mean scores were close to the normative mean of 22 for autism (autism range 15–30). As summarized in our Introduction, results reported in the literature regarding the association between atypical eating behaviors and total scores on autism measures are inconsistent. The high percentage of atypical eating behaviors, the link with the total CASD autism symptom score found in our study, and previous research showing that children with autism have a unique profile of atypical eating behaviors not found in children with other disorders or typical development (Mayes et al. 2018) suggest that atypical eating behaviors may be driven by an underlying mechanism that is intrinsically related to autism itself.

For children with autism who had atypical eating behaviors, limited food preferences was the most common type of atypical eating behavior (found in 87%), but the majority of children (60%) had more than one type of atypical eating behavior. Hypersensitivity to food texture was the second most common atypical eating behavior (found in 48%). Approximately half of children with limited food preferences were sensitive to food textures and half were not. Therefore, sensitivity to food textures may contribute to limited preferences in some cases, but is not the cause in at least half of cases.

Only two of the 29 CASD autism symptoms (tactile defensiveness and language regression between 1 and 2 years of age) were significantly more common in children with than without atypical eating behaviors in the univariate analyses. Suarez and Nelson (2012) and Farrow and Coulthard (2012) also found that tactile defensiveness, and not other sensory abnormalities, was related to limited food preferences in children with autism. However, in our study, when tactile defensiveness and language regression were considered together with other variables in regression analyses, they did not contribute uniquely beyond the four significant variables (higher total CASD score, young age, poor appetite, and constipation) in predicting the presence of atypical eating behaviors.

Our nonsignificant findings for most individual autism symptoms is consistent with results reported by Martins et al. (2008) who found that only one of the 30 autism symptoms (resistance to change) assessed by the CARS was associated with increased avoidance of new foods, food avoidance behaviors, and ritualistic eating behaviors in 41 children with autism, whereas all other CARS items (unusual sensory exploration and response, relating to people, imitation, emotional response, body use, object use, visual response, listening response, fear or nervousness, verbal communication, nonverbal communication, activity level, and level and consistency of intellectual response) were nonsignificant. Similarly, our study showed a nonsignificant relationship between atypical eating behaviors and 27 individual CASD autism symptoms reflecting social problems, repetitive interests and behaviors, resistance to change, and language, mood, behavior, attention, and sleep problems, as well as sensory-seeking behavior,

sensory under-responsivity (e.g., to pain and verbal input), and sensory-hypersensitivity (to sounds, smell, light, temperature, and how things feel such as touching certain things, being touched, or the feel of certain clothing). The difference between the two studies regarding the association with resistance to change is likely explained by how atypical eating behaviors were defined. Martins et al. (2008) included mealtime rituals in their definition of atypical eating behaviors. In contrast, in our study, mealtime rituals (e.g., insisting that food be arranged a certain way on a plate or using only a specific utensil) are part of the CASD resistance to change item and not the atypical eating behavior item because the behaviors involve how the food is presented and not types of food consumed.

Atypical eating behaviors in our study were not related to any of the PBS psychopathology scores, including oppositional behavior, conduct problems, ADHD, irritability, emotional overreactivity, anxiety, depression, and social problems. Our findings do not support those of previous and much smaller autism studies showing an association between limited food preferences and higher externalizing and internalizing problem rating scale scores (Postorino et al. 2015), tantrums (Dominick et al. 2007), and being "upset a great deal of the time" (Williams et al. 2000). In our large sample, tantrums, emotional distress, and several other CASD and PBS mood and behavior scores were not related to atypical eating behaviors.

Our study yielded important new information about psychotropic medication and atypical eating behaviors. Among children treated with psychotropic medication (32% of our sample), 57% were treated with a stimulant and 38% with an antipsychotic. Although potential side effects are a decrease in appetite for stimulants (Cortese et al. 2012) and weight gain for antipsychotics (McCracken et al. 2002; Nagaraj et al. 2006; Pandina et al. 2007), neither type of medication was associated with atypical eating behaviors. The same nonsignificant relationship was true for all other classes of psychotropic medications prescribed to children in our sample, including an SSRI, alpha agonist, anticonvulsant, atomoxetine, nonSSRI antidepressant, anxiolytic, and lithium.

Poor appetite and constipation were the only remaining study variables linked with atypical eating behaviors. Even though poor appetite was rated as often or very often a problem for 31% of children with atypical eating behaviors (three times higher than for children without atypical eating behaviors), the two groups did not differ significantly in parent-perceived weight problems. Therefore, maternal ratings of poor appetite may have been confounded by mothers conflating poor appetite and atypical eating behaviors. Body mass index was not related to food selectivity in the only previous autism study investigating these two variables (Postorino et al. 2015).

Constipation was the only GI problem assessed in our study significantly more common in children with versus without atypical eating behaviors. Nausea, vomiting, stomach aches, diarrhea, and bowel accidents were nonsignificant. The other health problems composite score (which included fatigue, headaches, dizziness, fevers, body aches and pains, and feeling sick) was not higher in children with versus without atypical eating behaviors, suggesting that atypical eating behaviors are not caused or aggravated by and do not result in these particular health problems. The relationship between atypical eating behaviors and constipation is interesting because grain products (most often pasta, breakfast foods, pizza, bread, crackers, and rice) comprised 72% of the preferred foods in a study of children with autism (Mayes et al. 2018). However, these are not predominantly whole grain foods and children with autism who have

limited preferences rarely eat vegetables and fruits, all of which are related to constipation (Tharner et al. 2015). Three of the four studies reviewed in our Introduction showed that food selectivity was not related to GI problems in children with autism.

Limitations and Directions for Future Research

Although our study had several strengths compared to most previous studies of atypical eating behaviors in autism (including a large sample size, a broad range of age and intellectual functioning, the use of a validated interviewer-administered measure to assess atypical eating, and the use of multivariate analyses with a large number of potential correlates), there were also significant limitations. One limitation was the use of a single item to assess atypical eating behaviors. This limitation is shared with much of the literature on eating in autism. Furthermore, atypical eating behaviors are often conceptualized and defined differently across studies and different terms and assessment measures are used, making it difficult to compare findings across studies and contributing to the apparent discrepancies between studies. The measure used in the present study included limited food preferences along with texture sensitivities, pica, pocketing, and other unusual eating behaviors such as brand specificity, whereas other studies have used narrower, broader, or different definitions of atypical eating behaviors. Our inclusion of other atypical eating behaviors in the same item makes it difficult to determine if our results apply primarily to limited food preferences (which is likely because 87% of our children with atypical eating behaviors had limited food preferences) versus the other atypical eating behaviors. Future research needs to analyze specific aspects of atypical eating behaviors separately. Further, our sub-item level analysis was based on a small subset of the total sample, so the results need to be replicated with a larger sample.

Another limitation of our study is the reliance on parent report to assess GI and health problems, appetite, and weight and not objective data. Further, the breath of health problems investigated in our study needs to be expanded in future research. Our "other health problems" composite score that did not include all potential health problems related to atypical eating behaviors, most notably inadequate nutritional status. Our study is also limited in that data were collected from one clinic and may not be representative of other autism samples and our children were predominantly white, limiting the ability to detect potential racial correlates of atypical eating behaviors. Last, more research is needed on the relationship between autism, atypical eating behaviors, and other correlates and symptoms that are most prominent during infancy and toddlerhood that could enhance screening practices and facilitate early identification.

Conclusion

In the largest sample to date investigating atypical eating behaviors in children with autism ($N = 1112$), atypical eating behaviors were common (found in 70.5%) and were related to higher autism symptom scores and younger age (although common at all ages). The finding regarding age is consistent with previous research showing that atypical eating behaviors are often present in infants with autism (Dominick et al. 2007) and the diets of children with autism are narrower than diets of typical peers by 15 months of age (Emond et al. 2010).

Other demographic variables in our study were not significantly related to atypical eating behaviors. Atypical eating behaviors were also not associated with behavior problems, anxiety, or other measures of psychopathology, or to psychotropic medication use. The only health concerns assessed in our study associated with the presence of atypical eating behaviors were constipation and reduced appetite (but not weight). The high prevalence of atypical eating behaviors in autism and the finding that atypical eating behaviors were most common in children 1–3 years of age (80%) have implications for practice. Developers of autism early screening measures should consider including atypical eating behaviors as a symptom. Primary care and early intervention providers should be aware that atypical eating behaviors are common in very young children with autism and, if present, should consider the possibility of autism and a referral for a diagnostic evaluation so that the child can access behavioral intervention shown to be effective in treating autism in toddlers and young preschoolers (Dawson et al. 2010; Harris and Handleman 2000), as well as in treating the atypical eating behaviors (Ledford and Gast 2006; Matson and Fodstad 2009).

Compliance with Ethical Standards

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was waived by the Institutional Review Board because analyses were conducted retrospectively on existing clinical data.

Conflict of Interest The authors declare they have no conflicts of interest.

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