Obesity and Autism

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abstract

OBJECTIVE: Overweight and obesity are increasingly prevalent in the general pediatric population. Evidence suggests that children with autism spectrum disorders (ASDs) may be at elevated risk for unhealthy weight. We identify the prevalence of overweight and obesity in a multisite clinical sample of children with ASDs and explore concurrent associations with variables identified as risk factors for unhealthy weight in the general population.

METHODS: Participants were 5053 children with confirmed diagnosis of ASD in the Autism Speaks Autism Treatment Network. Measured values for weight and height were used to calculate BMI percentiles; Centers for Disease Control and Prevention criteria for BMI for gender and age were used to define overweight and obesity (≥85th and ≥95th percentiles, respectively).

RESULTS: In children age 2 to 17 years, 33.6% were overweight and 18% were obese. Compared with a general US population sample, rates of unhealthy weight were significantly higher among children with ASDs ages 2 to 5 years and among those of non-Hispanic white origin. Multivariate analyses revealed that older age, Hispanic or Latino ethnicity, lower parent education levels, and sleep and affective problems were all significant predictors of obesity.

CONCLUSIONS: Our results indicate that the prevalence of unhealthy weight is significantly greater among children with ASD compared with the general population, with differences present as early as ages 2 to 5 years. Because obesity is more prevalent among older children in the general population, these findings raise the question of whether there are different trajectories of weight gain among children with ASDs, possibly beginning in early childhood.

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WHAT'S KNOWN ON THIS SUBJECT: Children and adolescents with autism spectrum disorders (ASDs) may be at elevated risk for unhealthy weight. Samples of children with verified clinical diagnoses of ASD have been lacking, and associations with child behavior and functioning are not well understood.

WHAT THIS STUDY ADDS: Young children (2–5 years old) and adolescents (12–17 years old) with ASDs were at an elevated risk for unhealthy weight status compared with a general population sample. The presence of sleep or affective problems may confer increased risk among those with ASD.

Pediatric overweight and obesity are significant public health concerns. In 2011 and 2012, 31.8% of US children aged 2 to 19 years were overweight (BMI ≥85th percentile)[1]; 16.9% were obese (BMI ≥95th percentile).[2] Unhealthy weight poses health risks including sleep-disordered breathing,[3] orthopedic problems,[4] type 2 diabetes,[5] hypertension and dyslipidemia,[6,7] and reduced life spans regardless of adult weight status.[8] Unhealthy weight is also associated with family economic burden[9,10] and harms psychosocial functioning[11,12]: Children who are overweight or obese are more likely to be bullied[13] and socially isolated.[14] Thus, unhealthy weight in childhood has significant implications for current quality of life and future independent functioning.[15]

Little is known about overweight and obesity in children with autism spectrum disorders (ASDs).[12] However, this issue is of increased public health importance because ASDs now affect 1 in 68 US children.[16] Although many risk factors for unhealthy weight are probably the same in children with ASDs as in the general pediatric population,[17,18] children with ASDs may be vulnerable to additional risks. For example, problem eating behaviors such as food selectivity are common among children with ASDs,[19–21] which tends to coincide with preferences for a narrow range of low-nutrition, energy-dense foods and rejection of fruits, vegetables, and whole grains.[19,22–24] Children with ASDs also spend more time in sedentary activities[25,26] and have less regular physical activity.[27,28] In addition, children with ASDs often take psychotropic medications,[29] many of which can cause weight gain.[30–32] Some children with ASDs may also have genetic vulnerabilities to obesity, such as 11p14.1 or 16p11.2 microdeletions.[33–35] Finally, having an ASD also increases the risk of comorbid problems[36,37] associated with unhealthy weight in childhood, such as sleep difficulties,[3,38] gastrointestinal (GI) disturbances,[39,40] attention-deficit/hyperactivity disorder (ADHD),[41] and disorders such as anxiety[42] and depression.[43]

The presence of these unique risk factors suggests that children with ASDs are at an elevated risk for being overweight or obese. However, prevalence estimates of unhealthy weight in ASD populations vary widely (Table 1). In 4 previous studies with non-ASD comparison groups, prevalence of obesity was higher among those with ASDs,[24,44–46] although the difference reached statistical significance in only 2 studies.[44,45] A recent study[45] found significantly higher prevalence of both overweight and obesity among children with ASDs, with group risks associated with older age, public insurance, and co-occurring sleep disorders.[45] However, previous studies have been limited by small samples,[24] use of parent-reported anthropometrics,[44,46] parent-reported ASD diagnosis,[44,46] or unconfirmed diagnoses present in medical records.[45,47] Additionally, associations between unhealthy weight and child behavior and functioning are not well understood among children with ASDs.

The first aim of this study was to examine prevalence of unhealthy weight in a large multisite sample of children with confirmed ASDs, based on measured weight and height. We compared these prevalence estimates with those derived from a US general population sample from the NHANES. The second aim was to examine family- and child-level factors associated with unhealthy weight among children with ASDs. Our final aim was to examine hypotheses regarding associations between unhealthy weight and factors unique to children with ASDs. We hypothesized that unhealthy weight among children with ASDs would be associated with greater impairments in behavioral functioning (ASD symptoms, adaptive skills). Based on results from a smaller sample of children with ASDs in Oregon,[48] we also expected obese children with ASDs to experience more comorbid problems (sleep difficulties, ADHD, internalizing symptoms such as depression and anxiety) and be prescribed psychotropic medications more often than nonobese children with ASDs.

METHODS

Participants

Participants included 5053 children enrolled in the Autism Speaks Autism Treatment Network (ATN) from 2008 to 2013 at 19 sites in the United States and Canada. The ATN registry includes children ages 2 to 17 years with confirmed ASDs per *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision*[49] criteria, supported by administration of the Autism Diagnostic Observation Schedule (ADOS).[50] Registry protocols are approved by each site's institutional review board.

NHANES Comparison Sample

The NHANES is a representative cross-sectional sample of the US noninstitutionalized population and is described elsewhere.[2] Weight and height values in NHANES are collected via standardized physical examination. We used data from 3 consecutive NHANES surveys (6 years) to account for secular changes in prevalence of overweight or obesity. We restricted the sample to children aged 2 to 17 years to match the age range in the ATN (unweighted n = 8844; weighted estimate of the total population size ≈ 63 157 608). The Supplemental Appendix details prevalence estimations in NHANES.

ATN Measures

Sociodemographics

Parents reported child gender, age, race or ethnicity, and parents'

TABLE 1 Summary of Prevalence Estimates for Overweight and Obesity (≥85th and ≥95th BMI Percentile for Age and Gender, Respectively) From Previous Studies Including Children With ASDs

Source	Location	Age Range, y	ASD, *n*	ASD Diagnostic Criteria	Wt/Height	Overweight, %	Obese, %
Ho et al (1997)[74]	Canada	School age	54			—	42.6
Whiteley et al (2004)[82]	UK	2–12	50	Previous clinical diagnosis; confirmed with ADI-R	Parent-reported	42.0	10.0
Curtin et al (2005)[47]	USA (MA)	3–18	140	Retrospective chart review	Measured	35.7	19.0
Xiong et al (2009)[83]	China	2–11	429	Parent-reported; confirmed with CARS	Measured	33.6	18.4
Chen et al (2010)[84]	USA	10–17	46 707	Parent-reported (telephone interview)	Parent-reported	—	23.4
Curtin et al (2010)[46]	USA	3–17	102 353	Parent-reported (telephone interview)	Parent-reported	—	30.4
Rimmer et al (2010)[85]	USA	12–18	461	Parent-reported (Web-based survey)	Parent-reported	42.5	24.6
Evans et al (2012)[24]	USA	3–11	53	Confirmed with ADI-R	Measured	—	17.0
Hyman et al (2012)[86]	USA	2–11	362	DSM-IV; confirmed with ADOS	Measured	—	8.3
Memari et al (2012)[87]	Iran	7–14	113	DSM-IV-TR; confirmed with ADI-R	Measured	40.7	27.4
Egan et al (2013)[70]	USA (MO)	2–5	273	Retrospective chart review	Measured	33.0	17.6
Zuckerman et al (2014)[48]	USA (OR)	2–18	376	DSM-IV-TR, ADOS	Measured	35.1	17.0
Phillips et al (2014)[44]	USA	12–17	93	Parent-reported (in-person interview)	Parent-reported	52.7	31.8
Broder-Fingert et al (2014)[45]	USA (MA)	2–20	2976	International Classification of Disease, Ninth Revision diagnosis of autism or Asperger syndrome	Measured	37.5	23.8

ADI-R, Autism Diagnostic Interview–Revised; CARS, Childhood Autism Rating Scale; DSM-IV-TR, *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision.*

education. Race was reported in 6 categories; these were collapsed to white, black, and other races for analyses because of sample size constraints. Ethnicity was categorized as Hispanic or Latino origin or not Hispanic or Latino. Parent education was grouped as high school graduate or less, some college, or college graduate or higher.

BMI

Trained clinical staff measured children's weight and height using a metric scale and wall-mounted stadiometer. These values were converted to gender-specific BMI-for-age percentiles based on Centers for Disease Control and Prevention (CDC) growth charts,[1] and CDC criteria were used to define overweight (BMI ≥85th percentile for age and gender) and obesity (BMI ≥95th percentile for age and gender). Underweight children (BMI <5th percentile; *n* = 237) were included in the denominator for prevalence estimates in both the ATN and NHANES samples but excluded from within-ATN subgroup comparisons.

Treatments

At registry entry, ATN clinicians record each child's prescribed psychotropic medications; dosage and duration of use are not recorded. We categorized medications as stimulants, selective serotonin reuptake inhibitors, nonstimulant ADHD medications, anticonvulsants, asthma and allergy medications, and atypical neuroleptics. For bivariate and multivariate logistic regression analyses, variables were collapsed into any or no prescribed psychotropic medications. Additional bivariate analyses examined associations of BMI category with total number of psychotropic medications as well as individual medication categories. Parents also reported use of complementary and alternative medications or treatments (CAM): chiropractic care, dietary supplements (amino acids, high-dose vitamin B6 and magnesium, essential fatty acids, probiotics, digestive enzymes, glutathione), or dietary interventions (gluten-free, casein-free, no processed sugars). Because of the infrequent rate of CAM endorsement, variables were collapsed into any or no CAM use. Current use of melatonin was measured as a separate variable.

Behavioral Functioning

Trained clinicians scored ASD symptoms during the ADOS,[50] a standardized observational assessment; ADOS calibrated severity scores (total CSS) provided a measure of overall ASD symptom severity.[51,52] Parents completed the Vineland Adaptive Behavior Scales (VABS-II),[53] which assesses functional skills and provides an Adaptive Behavior Composite as an estimate of overall adaptive functioning (mean = 100, SD = 15). We assessed intellectual functioning by using 1 of the following assessments (*N* = 3787): the full Stanford–Binet Scales of Intelligence (*n* = 753),[54] the abbreviated Stanford–Binet Scales of Intelligence (*n* = 1632), the Wechsler Intelligence Scale for Children, Fourth Edition (*n* = 141),[55] the Differential Ability Scales (*n* = 72),[56] the Wechsler Preschool and Primary Scale of Intelligence (*n* = 84),[57] the Wechsler Abbreviated Scale of Intelligence (*n* = 59),[58] the Leiter International Performance Scale–Revised (*n* = 108),[59] and the Mullen Scales of Early Learning (*n* = 938; Early Learning Composite Standard Scores).[60] Because Mullen Scales of Early Learning Early Learning Composite scores were skewed and could not be transformed, all children were grouped as IQ <70 (intellectual disability range) or not.

Comorbid Problems

Parents reported on children's sleep difficulties via the Children's Sleep Habits Questionnaire (CSHQ),[61] which measures 8 domains: bedtime resistance, sleep onset latency, sleep duration, anxiety around sleep, night awakenings, sleep-disordered breathing, parasomnias, and morning waking and daytime sleepiness. The total sleep disturbance score is the sum of scores across 33 items and served as a continuous measure of child sleep difficulties. In a separate questionnaire, parents reported whether they currently had concerns about their child's gastrointestinal (GI) difficulties ("gastrointestinal [belly] problems [diarrhea, constipation, pain]") as a "yes"/"no" response. Finally, parents completed the Child Behavior Checklist (CBCL), a validated parent questionnaire used to assess behavioral and emotional problems in both the general population and in ASD.[62] The CBCL Anxiety Problems scale includes items identified by experts as related to generalized anxiety disorder and specific phobias. The Affective Problems scale includes anxiety/depression, somatic complaints, and withdrawal.[63,64] The CBCL Attention Problems scale includes items related to inattention and hyperactivity associated with ADHD.

Statistical Analyses

Overweight and Obesity Among Children With ASDs Compared With the General Population

The goal of these analyses was to determine whether prevalence of overweight (≥85th percentile) or obesity (≥95th) was greater in children with ASDs than in a general population sample (NHANES). Underweight children were included in both samples. Because of NHANES's complex sampling structure, we conducted all analyses after applying sampling weights, using the R Survey package.[65,66] Weighted NHANES prevalence estimates were compared with those in the ATN sample via z tests. Within each set of comparisons (overweight and obesity), we adjusted P values to control Type I error rate at $q < 0.05$ by using the adaptive false discovery rate procedure (FDR).[67]

Associations With Overweight and Obesity in Children With ASDs

Bivariate and multivariate logistic regression models examined factors associated with overweight and obesity among children in the ATN. Sample size for each analysis differed because of missing data. To account for potential bias, we performed multiple imputation under the missing at random assumption to impute missing values.[68,69] Additional details of the multiple imputation procedure are reported in the Supplemental Appendix. For analyses, IQ standard scores and CBCL T scores were treated as categorical variables (<70 and ≥70, respectively), whereas ADOS CSS, CSHQ total sleep disturbance, and VABS-II Adaptive Behavior Composite scores were treated as continuous.

RESULTS

Overweight and Obesity Among Children With ASDs Compared With the General Population

Table 2 displays the characteristics of children with ASDs in the ATN. Compared with the general population, prevalence of overweight and obesity tended to be higher among children with ASDs (Table 3), but differences in overall rates were significant only among non-Hispanic white (ages 2–17) and Hispanic (ages 2–11) subgroups. Within age categories, prevalences of overweight and obesity were significantly higher among young children (age 2–5 years) with ASDs compared with the general population, except among non-Hispanic black children. Likewise, prevalences of overweight and obesity were significantly higher among adolescents (ages 12–17 years) with ASDs compared with the general population. However, for ages 6 to 11 years, no prevalence differences were found between the 2 samples.

Associations With Overweight and Obesity Among Children With ASDs (ATN Sample)

Results are presented in Table 4. After multivariate adjustment, age (6–11 years), black race, Hispanic or Latino ethnicity, and lower parental education retained associations with overweight status. Likewise, after multivariate adjustment, age <12 years, Hispanic or Latino ethnicity, lower parental education, and sleep and affective problems retained associations with obese weight status (Table 4). For each 1-unit increase in CSHQ scores, adjusted odds of obesity were 1.01 times greater. Similarly, the presence of affective problems on the CBCL was associated with 1.26 times the odds of obesity.

We conducted additional analyses of specific medication classes by classifying children into 3 groups based on their BMI percentiles: healthy weight (≥5 to <85), overweight but not obese (≥85 to <95), and obese (≥95). These analyses (not shown in tables; all P values adjusted with FDR and Cramer's V measure of effect size are reported) revealed no associations between BMI category and melatonin use (V = 0.03), dietary interventions (V = 0.03), stimulants (V = 0.03), nonstimulant ADHD medications (V = 0.01), and anticonvulsants (V = 0.01). Healthy weight children were less frequently prescribed selective serotonin reuptake inhibitors (4.8%) than overweight (7.0%; V = 0.04, P = .02) or obese children (7.9%; V = 0.06, P < .001). Compared with obese children, healthy weight children were less frequently prescribed atypical neuroleptics (4.8% vs 8.1%; V = 0.06, P < .001) and asthma and allergy medications (7.1% vs 10.1%; V = 0.05, P = .02). However, total psychotropic medications prescribed (range 0–5) was significantly associated with BMI category (Kruskal–Wallis rank sum test χ^2 = 10.2, P = .006). Pairwise Mann–Whitney U tests revealed that

TABLE 2 Sample Characteristics for Children With ASDs in the ATN by BMI Percentile Ranges (*N* = 5053)

	n (%) or Mean (SD)				Omnibus Test Statistic[a]
	<5th	≥5th to < 85th	≥85th to <95th	≥95th	
N	237	3118	789	909	
Age					χ^2 = 33.26 (P < .001)
2–5 y	139 (58.6)	1905 (61.1)[a]	484 (61.3)[a]	483 (53.1)[b]	
6–11 y	76 (32.1)	995 (31.9)[a,b]	235 (29.8)[b]	317 (34.9)[a]	
12–17 y	22 (9.3)	218 (7.0)[a]	70 (8.9)[a]	109 (12.0)[b]	
Gender					χ^2 = 0.09 (P = .96)
Male	204 (86.1)	2629 (84.3)	667 (84.5)	770 (84.7)	
Female	33 (13.9)	489 (15.7)	122 (15.5)	139 (15.3)	
Race					χ^2 = 11.16 (P = .02)
White	175 (73.8)	2396 (76.8)[a]	599 (75.9)[a]	695 (76.4)[a]	
Black	14 (5.9)	184 (5.9)[a]	60 (7.6)[a,b]	74 (8.1)[b]	
All other races or >1 race	34 (14.3)	394 (12.6)[a]	87 (11.0)[a,b]	92 (10.1)[b]	
Missing	14 (5.9)	144 (4.6)	43 (5.4)	48 (5.3)	
Ethnicity					χ^2 = 33.16 (P < .001)
Hispanic or Latino	12 (5.0)	256 (8.2)[a]	93 (11.8)[b]	133 (14.6)[b]	
Non-Hispanic or Latino	217 (91.6)	2728 (87.5)[a]	657 (83.3)[b]	743 (81.7)[b]	
Missing	8 (3.4)	134 (4.3)	39 (4.9)	33 (3.6)	
Parent education					χ^2 = 22.92 (P < .001)
High school or less	29 (12.2)	431 (13.8)[a]	121 (15.3)[a,b]	176 (19.4)[b]	
Some college	58 (24.5)	790 (25.3)[a]	207 (26.2)[a]	262 (28.8)[a]	
College graduate or more	134 (56.5)	1658 (53.2)[a]	402 (50.9)[a]	422 (46.4)[b]	
Missing	16 (6.7)	239 (7.7)	59 (7.5)	49 (5.4)	
Behavioral functioning					
ADOS CSS (10.2% missing)[b]	7.4 (1.9)	7.2 (1.9)	7.1 (1.9)	7.3 (1.8)	
VABS-II Adaptive Behavior (14.8% missing)[c]	71.8 (12.0)	72.1 (12.2)	71.3 (12.8)	70.0 (11.6)	
Full-scale IQ <70 (25.0% missing)	58 (24.5)	1003 (32.2)	256 (32.4)	310 (34.1)	χ^2 = 1.84 (P = .40)
Treatments					
Any psychotropic drug	68 (28.8)	823 (26.5)[a]	224 (28.6)[a,b]	286 (31.7)[b]	χ^2 = 9.27 (P = .01)
Any CAM	96 (19.4)	661 (21.2)	178 (22.6)	168 (18.5)	χ^2 = 4.70 (P = .09)
Comorbid problems					
CSHQ Sleep (26.5% missing)	47.8 (9.0)	48.0 (9.0)	48.1 (8.8)	49.3 (9.5)	
GI disturbance	79 (33.3)	890 (28.5)	205 (26.0)	247 (27.2)	χ^2 = 2.32 (P = .31)
CBCL Anxiety ≥70 (9.9% missing)	62 (26.2)	736 (23.6)	156 (19.8)	221 (24.3)	χ^2 = 5.10 (P = .08)
CBCL Affective ≥70 (9.9% missing)	66 (27.8)	794 (25.5)	178 (22.6)	281 (30.9)	χ^2 = 17.69 (P < .001)
CBCL ADHD ≥70 (9.9% missing)	42 (20.7)	647 (20.7)	153 (19.4)	198 (21.8)	χ^2 = 1.31 (P = .52)

ADOS CSS, Autism Diagnostic Observation Schedule Calibrated Severity Score.

BMI for age percentiles based on CDC growth charts. For each variable, if the omnibus test statistic was less than P = .05, post hoc comparisons were conducted. Column values within the same row that differ at least at the P = .05 level are denoted by different superscripts (eg, 5^a vs 10^b); column values within the same row that share the same superscript did not differ (eg, 5^a vs 6^a). See Table 4 for corresponding analyses involving multiply imputed data and Supplemental Table 1 for test statistics based on complete case analysis.

a Analyses exclude children with BMI <5th percentile.

b ADOS CSSs range from 1 to 10.

c VABS-II Adaptive Behavior Composite standard scores (mean = 100, SD = 15).

children in the obesity group received more medications than those in the healthy weight group (Cohen's d = 0.14; FDR adjusted P = .005).

DISCUSSION

In this multi-institutional sample of children with ASDs, 33.6% of children met criteria for overweight (≥85th BMI percentile), and 18% met criteria for obesity (≥95th BMI percentile). The prevalence estimate for overweight is comparable to the 31.8% prevalence among same-age children in the general population from NHANES. Prevalence of overweight and obesity among children with ASDs was significantly higher at younger age (2–5 years) and in adolescence (12–17 years) compared with the general population sample from NHANES. These prevalence estimates are consistent with recently reported estimates based on measured height and weight in people with ASDs.[45,70] For example, Broder-Fingert et al[45] found significantly elevated rates of overweight (exclusive of obesity) and obese weight status among children with Asperger syndrome and autism compared with control children in every age category (2–5, 6–11, 12–15, and 16–20 years). In our analyses, prevalence of overweight and obesity was consistently higher for ASDs, except among children with ASDs ages 6–11 years. One explanation for this discrepancy may be that Broder-Fingert's control group had lower prevalence of overweight (inclusive of obesity) than this study's general population sample. For example, among children age 6–11 years,

TABLE 3 Comparisons of Prevalence Estimates for Overweight and Obesity (≥85th and ≥95th Percentile for Age and Gender, Respectively) Between the ATN and NHANES Data Sets

	Age Range, y	Unweighted Sample Sizes[a]		Overweight, % (95% CI)		z	P	Obese, % (95% CI)		z	P
		ATN	NHANES[b]	ATN	NHANES[b]			ATN	NHANES[b]		
All[b]											
	All (2–17)	5053	8844	33.6 (32.3–35.0)	31.8 (30.5–33.0)	1.86	.057	18.0 (17.0–19.0)	16.7 (15.7–18.0)	1.57	.120
	2–5	3011	2627	32.1 (30.5–33.8)	23.4 (21.2–25.7)	6.06	<.001	16.0 (14.8–17.4)	10.1 (8.8–11.6)	6.02	<.001
	6–11	1623	3678	34.0 (31.8–36.4)	34.2 (32.5–36.1)	−0.15	.464	19.5 (17.7–21.5)	18.5 (17.1–20.0)	0.84	.303
	12–17	419	2539	42.7 (38.1–47.5)	35.3 (33.1–37.5)	2.79	.006	26.0 (22.0–30.4)	19.5 (17.9–21.3)	2.79	.010
Boys[c]											
	All (2–17)	4270	4543	33.7 (32.3–35.1)	32.5 (30.8–34.2)	1.02	.206	18.0 (16.9–19.2)	17.5 (16.0–19.1)	0.54	.371
	2–5	2531	1375	32.2 (30.4–34.1)	24.5 (21.8–27.4)	4.48	<.001	16.0 (14.6–17.4)	11.0 (9.2–13.1)	4.01	<.001
	6–11	1384	1866	34.2 (31.8–36.8)	34.2 (31.7–36.9)	0.01	.498	20.2 (18.1–22.4)	19.3 (17.7–21.1)	0.60	.364
	12–17	355	1302	41.4 (36.4–46.6)	36.4 (32.9–40.1)	1.56	.091	24.5 (20.3–29.2)	20.3 (17.5–23.3)	1.55	.120
Girls[c]											
	All (2–17)	783	4301	33.3 (30.1–36.7)	31.2 (29.4–33.0)	1.13	.184	17.7 (15.2–20.6)	15.9 (14.8–17.2)	1.19	.201
	2–5	480	1252	31.5 (27.5–35.8)	22.1 (19.0–25.6)	3.43	.001	16.5 (13.4–20.0)	9.2 (7.2–11.7)	3.54	.001
	6–11	239	1812	32.6 (27.0–38.8)	34.2 (31.5–37.1)	−0.48	.378	15.9 (11.8–21.1)	17.6 (15.9–19.5)	−0.69	.348
	12–17	64	1237	50.0 (38.1–61.9)	34.1 (31.2–37.2)	2.46	.014	34.4 (23.9–46.6)	18.8 (17.0–20.8)	2.58	.013
Non-Hispanic white											
	All (2–17)	3486	2553	32.3 (30.8–33.9)	28.8 (26.8–30.9)	2.65	.009	17.3 (16.1–18.6)	14.2 (12.4–16.1)	2.71	.010
	2–5	1994	778	31.4 (29.4–33.5)	20.6 (17.4–24.2)	5.32	<.001	15.7 (14.2–17.4)	7.2 (5.5–9.3)	6.68	<.001
	6–11	1170	1046	31.4 (28.8–34.1)	30.6 (27.7–33.7)	0.37	.396	17.6 (15.5–19.9)	15.4 (13.0–18.1)	1.30	.179
	12–17	322	729	41.9 (36.7–47.4)	32.3 (29.2–35.7)	2.97	.005	25.8 (21.3–30.8)	17.4 (14.8–20.4)	2.96	.007
Non-Hispanic black											
	All (2–17)	277	2194	37.9 (32.4–43.7)	36.4 (34.1–38.8)	0.46	.378	21.3 (16.9–26.5)	21.1 (19.1–23.3)	0.06	.573
	2–5	177	620	32.2 (25.8–39.4)	25.2 (22.0–28.7)	1.79	.061	16.9 (12.1–23.2)	13.6 (10.9–16.9)	1.03	.241
	6–11	70	912	47.1 (35.9–58.7)[d]	39.8 (36.2–43.5)	–	–	31.4 (21.8–43.0)[d]	24.0 (20.8–27.6)	–	–
	12–17	30	662	50.0 (33.2–66.8)[d]	40.8 (36.6–45.1)	–	–	23.3 (11.8–41.0)[d,e]	23.4 (19.6–27.8)	–	–
Hispanic[f]											
	All (2–17)	494	3189	45.7 (41.4–50.2)	38.8 (37.3–40.4)	2.91	.005	26.9 (23.2–31.0)	22.0 (20.9–23.2)	2.35	.023
	2–5	306	950	42.8 (37.4–48.4)	29.8 (27.3–32.5)	4.15	<.001	22.9 (18.5–27.9)	15.5 (13.4–18.0)	2.73	.010
	6–11	159	1372	50.9 (43.2–58.6)[d]	43.0 (40.6–45.6)	–	–	33.3 (26.5–41.0)[d]	24.8 (22.9–26.8)	–	–
	12–17	29	867	48.3 (31.4–65.5)[d]	41.5 (37.9–45.3)	–	–	34.5 (19.9–52.6)[d,e]	24.3 (21.7–27.1)	–	–

Positive *z* scores indicate that the ATN prevalence is greater than that in NHANES. All *P* values are adjusted; see text for details. 95% CIs calculated with logit transformation.

a Including underweight children in both samples.

b Data from NHANES years 2007 to 2008, 2009 to 2010, and 2011 to 2012; prevalence estimates are weighted with 6-y weights (see the Appendix for details).

c Includes other race and ethnic groups not shown separately, including multiracial, non-Hispanic Asian, American Indian or Alaskan Native, Native Hawaiian, or Pacific Islander.

d Sample size <50 and are excluded from significance testing.

e Relative standard errors >25% but <35%.

f For both ATN and NHANES, children whose parents reported Hispanic or Latino origin were categorized as Hispanic or Latino regardless of their race.

<20% of children in Broder-Fingert's sample had BMI ≥85th percentile for gender and age, compared with 34.2% in NHANES.

Examination of cross-sectional prevalence estimates (Table 3) also suggests the possibility of different age-related trends among children with ASDs. For example, in the general population, prevalence of overweight was 10.9% higher among children ages 6 to 11 years than among those ages 2–5 years. In contrast, in the ATN, prevalence was only 1.9% higher among children age 6–11 versus 2–5 years. Because obesity becomes more prevalent among older children in the general population,[2] these findings may suggest a different trajectory of weight gain among children with ASD. The lack of differences in the prevalence of overweight and obesity between the ages of 6 and 11 years might reflect a stabilizing period, in which children with ASDs who gained weight earlier remain in the same BMI category. In contrast, children in the general population may be more likely to gain excess weight at older ages. Future longitudinal analyses could explore these trends in greater detail.

One surprising finding was the lack of differences between the ASD sample and the general population among children of non-Hispanic black origin. Environmental factors associated with obesity, such as socioeconomic status, are probably already elevated among black children[71,72] and may overshadow additional risks associated with ASDs. Alternatively, given that the ATN constitutes a referred sample, black children in the ATN may be of higher socioeconomic status and therefore differ less systematically than white children, regardless of ASD status. However, this latter explanation would be inconsistent with the robust differences we found between

TABLE 4 Multivariate Analyses Using Multiple Imputation (N = 4816) to Predict Overweight and Obesity (≥85th and ≥95th Percentile for Age and Gender, Respectively) Among Children With ASDs

Variable	*n* (%) Complete	OR (95% CI)			
		Univariate (Crude OR)		Multivariate (Adjusted OR)	
		Overweight	Obesity	Overweight	Obesity
Age, *n* (%)	4816 (100.0)				
2–5 y		Reference	Reference	Reference	Reference
6–11 y		1.09 (0.96–1.24)	1.27 (1.09–1.49)**	1.12 (0.97–1.30)	1.35 (1.13–1.60)**
12–17 y		1.62 (1.31–2.00)**	1.87 (1.47–2.38)**	1.62 (1.28–2.05)**	1.95 (1.49–2.60)**
Male, *n* (%)	4816 (100.0)	1.02 (0.87–1.21)	1.03 (0.84–1.25)	1.01 (0.86–1.20)	1.02 (0.83–1.25)
Race, *n* (%)	4581 (95.1)				
White		Reference	Reference	Reference	Reference
Black		1.37 (1.09–1.72)**	1.34 (1.02–1.76)*	1.27 (1.00–1.60)*	1.22 (0.92–1.62)
All other races		0.83 (0.69–1.01)	0.82 (0.65–1.04)	0.85 (0.70–1.04)	0.86 (0.67–1.09)
Hispanic or Latino, *n* (%)	4610 (95.7)	1.72 (1.42–2.08)**	1.72 (1.39–2.13)**	1.66 (1.37–2.02)**	1.63 (1.30–2.03)**
Parent education, *n* (%)	4489 (93.2)				
High school or less		Reference	Reference	Reference	Reference
Some college		0.88 (0.72–1.07)	0.85 (0.67–1.06)	0.92 (0.75–1.13)	0.88 (0.70–1.12)
College graduate or more		0.73 (0.62–0.88)**	0.66 (0.54–0.82)**	0.81 (0.67–0.97)*	0.75 (0.60–0.94)*
Behavioral functioning					
ADOS CSS, mean (SD)	4322 (89.7)	1.00 (0.97–1.04)	1.02 (0.98–1.07)	0.99 (0.96–1.03)	1.02 (0.98–1.06)
VABS-II Adaptive Behavior, mean (SD)	4102 (85.2)	0.99 (0.99–1.00)**	0.99 (0.99–1.00)*	1.00 (0.99–1.00)	1.00 (0.99–1.00)
Full-scale IQ <70, *n* (%)	3620 (75.2)	1.10 (0.96–1.24)	1.08 (0.92–1.27)	1.04 (0.90–1.21)	1.10 (0.91–1.33)
Treatments					
Any psychotropic drugs	4816 (100.0)	1.20 (1.05–1.36)**	1.25 (1.07–1.47)**	1.11 (0.96–1.28)	1.06 (0.88–1.26)
Any CAM	4816 (100.0)	0.95 (0.82–1.10)	0.83 (0.69–0.98)*	1.01 (0.87–1.18)	0.87 (0.72–1.05)
Comorbid problems					
CSHQ Sleep, mean (SD)	3538 (73.5)	1.01 (1.00–1.01)*	1.02 (1.01–1.02)**	1.01 (1.00–1.02)	1.01 (1.00–1.02)*
GI disturbance, *n* (%)	4816 (100.0)	0.91 (0.79–1.04)	0.96 (0.81–1.13)	0.88 (0.77–1.02)	0.92 (0.77–1.09)
CBCL Anxiety ≥70, *n* (%)	4339 (90.1)	0.97 (0.84–1.12)	1.12 (0.95–1.33)	0.86 (0.73–1.01)	0.91 (0.75–1.10)
CBCL Affective ≥70, *n* (%)	4339 (90.1)	1.10 (0.96–1.26)	1.36 (1.16–1.60)**	1.06 (0.90–1.25)	1.26 (1.04–1.53)*
CBCL ADHD ≥70, *n* (%)	4338 (90.1)	1.02 (0.88–1.19)	1.09 (0.91–1.30)	0.95 (0.81–1.12)	0.94 (0.78–1.14)

ADOS CSS, Autism Diagnostic Observation Schedule Calibrated Severity Score; OR, odds ratio. * $P < .05$; ** $P < .01$. Variables without missing data were present in the imputation model but were not imputed.

Hispanic children in the ASD and general populations, because Hispanic children may also have elevated environmental risks.[73] Because the sample sizes of non-Hispanic black children with ASDs in the ATN were small, group estimates may also be less reliable.

Among children with ASDs, there were several notable associations between sociodemographic variables and unhealthy weight. Multivariate analyses revealed that older age, Hispanic or Latino ethnicity, lower parent education, and sleep and affective problems were significantly associated with obesity. Many of these factors confirm previous findings in a smaller sample of children with ASDs in Oregon[48] and another recent large-scale study.[45] Because our study is cross-sectional, it is not clear whether comorbid sleep and affective problems are a cause or a consequence of obesity. Repeated measures could clarify these associations and might reveal important inroads to prevention and treatment of overweight and obesity among children with ASD.

Notably, some variables had no association with unhealthy weight among children with ASDs. In contrast to previous studies,[70,74] there was no significant association between severity of ASD symptoms, and neither adaptive nor intellectual functioning was associated with overweight or obesity in multivariate models. In contrast to studies of typically developing children[75,76] but consistent with previous research in children with ASDs,[77] GI problems were not linked to overweight or obesity. Also in contrast to findings in the general population,[41,42] ADHD and anxiety problems were not associated with overweight or obesity. Thus, interventions that take into account both general risk factors for unhealthy weight and those that are ASD specific may hold promise for improved weight status in ASDs.

This study has limitations. Because it is a secondary data analysis, there was limited detail about sociodemographics, developmental and family history, GI problems, and medication dosages or duration of use. Our analysis of medications was limited by the available data in the ATN; other medications may have an impact on obesity that we were unable to estimate. For example, as 1 reviewer noted, medications with soporific effects could be linked to unhealthy weight status, but we were unable to explore these types of associations with the data collected.

The effect of parent education levels on children's weight status may also be underestimated in this sample, given the slightly skewed range in the ATN (<2.2% had parents with less than high school education); to preserve statistical power, we did not analyze this category separately. In addition, although highly correlated with body fat, BMI is an imperfect measure because it does not distinguish between fat and lean body mass.[78,79] Children of different ages, genders, and race and ethnicity groups may differ in body fat composition despite having similar BMI.[81] We could not measure several variables that are likely to be important for BMI such as dietary intake and physical activity. In addition, there was no measure of parental BMI or family environment,[80] which are associated with children's BMI. Finally, in interpreting findings, it is important to note that the group of children ages 2 to 5 years may be the most representative sample of children with ASDs, given a median age of diagnosis of 4.4 years of age in the United States[16] and that enrollment in the ATN registry can often occur at the time of diagnosis. The clinic-referred sample of children available in the ATN may also have more frequent or more severe health problems than the larger population of children with ASDs.

CONCLUSIONS

Despite these limitations, this is the first multicenter study to assess unhealthy weight risk in ASDs, as well as overweight and obesity risk factors, in a population with both verified ASDs and directly measured biometrics. The study provides strong confirmatory evidence that young children with ASDs are at risk for unhealthy weight trajectories and that the presence of sleep or affective problems may confer increased risk. The findings suggest that health care providers should talk with families early about the risk of unhealthy weight in ASDs, particularly when other comorbid conditions exist.

ABBREVIATIONS

ADHD: attention-deficit/hyperactivity disorder
ADOS: Autism Diagnostic Observation Schedule
ASD: autism spectrum disorder
ATN: autism treatment network
CAM: complementary and alternative medications or treatments
CBCL: Child Behavior Checklist
CDC: Centers for Disease Control and Prevention
CI: confidence interval
CSHQ: Children's Sleep Habits Questionnaire
CSS: calibrated severity score
GI: gastrointestinal
VABS-II: Vineland Adaptive Behavior Scales

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HIDDEN FEES: *I tend to scour the internet for the best rates for airline travel, hotel rooms, and concert tickets. While I dislike the unexplained "fees" that are added to the cost, particularly for concert tickets, I principally hate not knowing the true cost of the product until the very end of the transaction. While airline fees and taxes are quite high, at least most online airline pricing sites are fairly good at presenting the total cost of the flight early in the process. I tend to find that buying a concert ticket is remarkably galling as trying to understand the checkout price (i.e., the total cost of the ticket) is extremely challenging. I was quite happy when the company with the largest share of the $6 billion live-event ticket market decided to shift to "all-in" pricing where the total cost of the ticket – including any convenience fees – is shown up front.*

As reported in The Wall Street Journal *(Business: August 31, 2015), however, other resellers did not follow suit. Their prices, at least at first glance, appeared much better than the company using the "all-in" pricing strategy. This led to a precipitous decline in business for the company using the "all-in" pricing strategy. It turns out that while consumers purchasing concert tickets online routinely cite separate service charges as their top annoyance, they really hate seeing that cost front loaded into the sticker price. In a head to head comparison, shoppers were much more inclined to purchase tickets with a lower introductory cost regardless of the final cost. The company has since abandoned the "all-in" pricing policy. Those in the industry are not surprised by the findings, stating that most e-consumers do not consider the checkout price. After all, if one buys a 99-cent candy bar the checkout cost is over a dollar.*

While I cannot comment on the average e-consumer, I do know for a fact that if I purchase a product in Vermont where I live, the state sales tax is 6% and there are no other convenience fees—at least for now.

Noted by WVR, MD