

Obesity and Autism

Alison Presmanes Hill, PhD^a, Katharine E. Zuckerman, MD, MPH^b, Eric Fombonne, MD^c

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 (≥ 85 th and ≥ 95 th 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.



^aCenter for Spoken Language Understanding, Institute for Development & Disability, Department of Pediatrics; ^bDivision of General Pediatrics, Doernbecher Children's Hospital; and ^cDepartment of Psychiatry, Institute for Development & Disability, Oregon Health & Science University, Portland Oregon

Dr Hill conducted all analyses, drafted the initial manuscript, and reviewed and revised the manuscript; Dr Zuckerman consulted on all analyses, drafted the initial manuscript, and reviewed and revised the manuscript; Dr Fombonne consulted on all analyses and critically reviewed the manuscript; and all authors approved the final manuscript as submitted.

www.pediatrics.org/cgi/doi/10.1542/peds.2015-1437

DOI: 10.1542/peds.2015-1437

Accepted for publication Sep 3, 2015

Address correspondence to Alison Presmanes Hill, PhD, 3181 SW Sam Jackson Park Road GH 40, Portland, OR 97239. E-mail: hillali@ohsu.edu

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

Copyright © 2015 by the American Academy of Pediatrics

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 \geq 85th percentile)¹; 16.9% were obese (BMI \geq 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 bullied¹³ 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 anxiety⁴² 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 study⁴⁵ 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 $\approx 63\,157\,608$). 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 (≥ 85 th and ≥ 95 th BMI Percentile for Age and Gender, Respectively) From Previous Studies Including Children With ASDs

Source	Location	Age Range, y	ASD, <i>n</i>	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 ≥ 85 th percentile for age and gender) and obesity (BMI ≥ 95 th percentile for age and gender). Underweight children (BMI < 5 th 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 (≥ 85 th percentile) or obesity (≥ 95 th) 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 $\chi^2 = 10.2$, $P = .006$). Pairwise Mann-Whitney U tests revealed that

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

	<i>n</i> (%) or Mean (SD)				Omnibus Test Statistic ^a
	<5th	≥5th to < 85th	≥85th to <95th	≥95th	
<i>N</i>	237	3118	789	909	
Age					$\chi^2 = 33.26$ ($P < .001$)
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					$\chi^2 = 0.09$ ($P = .96$)
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					$\chi^2 = 11.16$ ($P = .02$)
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					$\chi^2 = 33.16$ ($P < .001$)
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					$\chi^2 = 22.92$ ($P < .001$)
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)	$\chi^2 = 1.84$ ($P = .40$)
Treatments					
Any psychotropic drug	68 (28.8)	823 (26.5) ^a	224 (28.6) ^{a,b}	286 (31.7) ^b	$\chi^2 = 9.27$ ($P = .01$)
Any CAM	96 (19.4)	661 (21.2)	178 (22.6)	168 (18.5)	$\chi^2 = 4.70$ ($P = .09$)
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)	$\chi^2 = 2.32$ ($P = .31$)
CBCL Anxiety ≥70 (9.9% missing)	62 (26.2)	736 (23.6)	156 (19.8)	221 (24.3)	$\chi^2 = 5.10$ ($P = .08$)
CBCL Affective ≥70 (9.9% missing)	66 (27.8)	794 (25.5)	178 (22.6)	281 (30.9)	$\chi^2 = 17.69$ ($P < .001$)
CBCL ADHD ≥70 (9.9% missing)	42 (20.7)	647 (20.7)	153 (19.4)	198 (21.8)	$\chi^2 = 1.31$ ($P = .52$)

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 al⁴⁵ 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 (≥ 85 th and ≥ 95 th 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 ≥ 85 th 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 (≥ 85 th and ≥ 95 th Percentile for Age and Gender, Respectively) Among Children With ASDs

Variable	<i>n</i> (%) Complete	OR (95% CI)			
		Univariate (Crude OR)		Multivariate (Adjusted OR)	
		Overweight	Obesity	Overweight	Obesity
Age, <i>n</i> (%)	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, <i>n</i> (%)	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, <i>n</i> (%)	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, <i>n</i> (%)	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, <i>n</i> (%)	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, <i>n</i> (%)	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, <i>n</i> (%)	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 , <i>n</i> (%)	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 , <i>n</i> (%)	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 , <i>n</i> (%)	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 Oregon⁴⁸ 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 States¹⁶ 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

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDING: This research was conducted by using data collected as part of the Autism Treatment Network (ATN). The ATN is funded by Autism Speaks and a cooperative agreement (UA3 MC 11054) from the Health Resources and Services Administration to Massachusetts General Hospital. This project was funded by an ATN/Autism Intervention Research Network on Physical Health grant (principal investigator: Dr Fombonne). Dr Zuckerman's effort was funded by K23MH095828 from the US National Institute of Mental Health. Funded by the National Institutes of Health (NIH).

POTENTIAL CONFLICT OF INTEREST: Drs Zuckerman and Fombonne have received grants from Autism Speaks for other projects. Dr Fombonne has served as an expert witness on autism-related cases for AbbVie and GlaxoSmithKline. Dr Hill has indicated she has no potential conflicts of interest to disclose.

REFERENCES

- Kuczumarski RJ, Ogden CL, Guo SS, et al. 2000 CDC growth charts for the United States: methods and development. *Vital Health Stat 11*. 2002; No. 246:1–190
- Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011–2012. *JAMA*. 2014;311(8):806–814
- Bixler EO, Vgontzas AN, Lin HM, et al. Sleep disordered breathing in children in a general population sample: prevalence and risk factors. *Sleep*. 2009; 32(6):731–736
- Taylor ED, Theim KR, Mirch MC, et al. Orthopedic complications of overweight in children and adolescents. *Pediatrics*. 2006;117(6):2167–2174
- Goran MI, Ball GDC, Cruz ML. Obesity and risk of type 2 diabetes and cardiovascular disease in children and adolescents. *J Clin Endocrinol Metab*. 2003;88(4):1417–1427
- Friedemann C, Heneghan C, Mahtani K, Thompson M, Perera R, Ward AM. Cardiovascular disease risk in healthy children and its association with body mass index: systematic review and meta-analysis. *BMJ*. 2012;345:e4759
- Freedman DS, Mei Z, Srinivasan SR, Berenson GS, Dietz WH. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa Heart Study. *J Pediatr*. 2007;150(1):12–17.e2
- Must A, Phillips SM, Naumova EN. Occurrence and timing of childhood overweight and mortality: findings from the Third Harvard Growth Study. *J Pediatr*. 2012;160(5):743–750
- Trasande L, Chatterjee S. The impact of obesity on health service utilization and costs in childhood. *Obesity (Silver Spring)*. 2009;17(9):1749–1754
- Wang G, Dietz WH. Economic burden of obesity in youths aged 6 to 17 years:

- 1979–1999. *Pediatrics*. 2002;109(5). Available at: www.pediatrics.org/cgi/content/full/109/5/e81
11. Lobstein T, Baur L, Uauy R; IASO International Obesity TaskForce. Obesity in children and young people: a crisis in public health. *Obes Rev*. 2004;5(suppl 1): 4–104
 12. Grondhuis SN, Aman MG. Overweight and obesity in youth with developmental disabilities: a call to action. *J Intellect Disabil Res*. 2014;58(9):787–799
 13. Janssen I, Craig WM, Boyce WF, Pickett W. Associations between overweight and obesity with bullying behaviors in school-aged children. *Pediatrics*. 2004; 113(5):1187–1194
 14. Strauss RS, Pollack HA. Social marginalization of overweight children. *Arch Pediatr Adolesc Med*. 2003;157(8): 746–752
 15. Curtin C, Jojic M, Bandini LG. Obesity in children with autism spectrum disorder. *Harv Rev Psychiatry*. 2014;22(2):93–103
 16. Centers for Disease Control and Prevention (CDC). Prevalence of autism spectrum disorder among children aged 8 years: autism and developmental disabilities monitoring network, 11 sites, United States, 2010. *MMWR Surveill Summ*. 2014;63(2):1–21
 17. Kipping RR, Jago R, Lawlor DA. Obesity in children. Part 1: epidemiology, measurement, risk factors, and screening. *BMJ*. 2008;337(7675):a1824
 18. Kirk SFL, Penney TL, McHugh T-LF. Characterizing the obesogenic environment: the state of the evidence with directions for future research. *Obes Rev*. 2010;11(2):109–117
 19. Schreck KA, Williams K, Smith AF. A comparison of eating behaviors between children with and without autism. *J Autism Dev Disord*. 2004;34(4):433–438
 20. Sharp WG, Berry RC, McCracken C, et al. Feeding problems and nutrient intake in children with autism spectrum disorders: a meta-analysis and comprehensive review of the literature. *J Autism Dev Disord*. 2013;43(9): 2159–2173
 21. Martins Y, Young RL, Robson DC. Feeding and eating behaviors in children with autism and typically developing children. *J Autism Dev Disord*. 2008;38(10): 1878–1887
 22. 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(5):505–511
 23. Williams KE, Gibbons BG, Schreck KA. Comparing selective eaters with and without developmental disabilities. *J Dev Phys Disabil*. 2005;17(3):299–309
 24. Evans EW, Must A, Anderson SE, et al. Dietary patterns and body mass index in children with autism and typically developing children. *Res Autism Spectr Disord*. 2012;6(1):399–405
 25. Must A, Phillips SM, Curtin C, et al. Comparison of sedentary behaviors between children with autism spectrum disorders and typically developing children. *Autism*. 2014;18(4):376–384
 26. Mazurek MO, Engelhardt CR. Video game use in boys with autism spectrum disorder, ADHD, or typical development. *Pediatrics*. 2013;132(2):260–266
 27. Macdonald M, Esposito P, Ulrich D. The physical activity patterns of children with autism. *BMC Res Notes*. 2011;4(1): 422
 28. Bandini LG, Gleason J, Curtin C, et al. Comparison of physical activity between children with autism spectrum disorders and typically developing children. *Autism*. 2013;17(1):44–54
 29. Coury DL, Anagnostou E, Manning-Courtney P, et al. Use of psychotropic medication in children and adolescents with autism spectrum disorders. *Pediatrics*. 2012;130(suppl 2):S69–76
 30. Correll CU, Manu P, Olshanskiy V, Napolitano B, Kane JM, Malhotra AK. Cardiometabolic risk of second-generation antipsychotic medications during first-time use in children and adolescents. *JAMA*. 2009;302(16): 1765–1773
 31. De Hert M, Detraux J, van Winkel R, Yu W, Correll CU. Metabolic and cardiovascular adverse effects associated with antipsychotic drugs. *Nat Rev Endocrinol*. 2012;8(2):114–126
 32. Williamson ED, Martin A. Psychotropic medications in autism: practical considerations for parents. *J Autism Dev Disord*. 2012;42(6):1249–1255
 33. Jacquemont S, Raymond A, Zufferey F, et al. Mirror extreme BMI phenotypes associated with gene dosage at the chromosome 16p11.2 locus. *Nature*. 2011;478(7367):97–102
 34. Weiss LA, Shen Y, Korn JM, et al; Autism Consortium. Association between microdeletion and microduplication at 16p11.2 and autism. *N Engl J Med*. 2008; 358(7):667–675
 35. Shinawi M, Sahoo T, Maranda B, et al. 11p14.1 microdeletions associated with ADHD, autism, developmental delay, and obesity. *Am J Med Genet A*. 2011;155A(6): 1272–1280
 36. Krakowiak P, Goodlin-Jones B, Hertz-Picciotto I, Croen LA, Hansen RL. Sleep problems in children with autism spectrum disorders, developmental delays, and typical development: a population-based study. *J Sleep Res*. 2012;21(2):231–231
 37. Leyfer OT, Folstein SE, Bacalman S, et al. Comorbid psychiatric disorders in children with autism: interview development and rates of disorders. *J Autism Dev Disord*. 2006;36(7):849–861
 38. Dev DA, McBride BA, Fiese BH, Jones BL, Cho H; on behalf of the Strong Kids Research Team. Risk factors for overweight/obesity in preschool children: an ecological approach. *Child Obes*. 2013;9(5):399–408
 39. Delgado-Aros S, Locke GR III, Camilleri M, et al. Obesity is associated with increased risk of gastrointestinal symptoms: a population-based study. *Am J Gastroenterol*. 2004;99(9):1801–1806
 40. Talley NJ, Howell S, Poulton R. Obesity and chronic gastrointestinal tract symptoms in young adults: a birth cohort study. *Am J Gastroenterol*. 2004; 99(9):1807–1814
 41. Waring ME, Lapane KL. Overweight in children and adolescents in relation to attention-deficit/hyperactivity disorder: results from a national sample. *Pediatrics*. 2008;122(1). Available at: www.pediatrics.org/cgi/content/full/122/1/e1
 42. Rofey DL, Kolko RP, Iosif A-M, et al. A longitudinal study of childhood depression and anxiety in relation to weight gain. *Child Psychiatry Hum Dev*. 2009;40(4):517–526
 43. Faith MS, Butryn M, Wadden TA, Fabricatore A, Nguyen AM, Heymsfield SB. Evidence for prospective associations

- among depression and obesity in population-based studies. *Obes Rev*. 2011;12(5):e438–e453
44. Phillips KL, Schieve LA, Visser S, et al. Prevalence and impact of unhealthy weight in a national sample of US adolescents with autism and other learning and behavioral disabilities. *Matern Child Health J*. 2014;18(8):1964–1975
 45. Broder-Fingert S, Brazauskas K, Lindgren K, Iannuzzi D, Van Cleave J. Prevalence of overweight and obesity in a large clinical sample of children with autism. *Acad Pediatr*. 2014;14(4):408–414
 46. Curtin C, Anderson SE, Must A, Bandini L. The prevalence of obesity in children with autism: a secondary data analysis using nationally representative data from the National Survey of Children's Health. *BMC Pediatr*. 2010;10:11
 47. Curtin C, Bandini LG, Perrin EC, Tybor DJ, Must A. Prevalence of overweight in children and adolescents with attention deficit hyperactivity disorder and autism spectrum disorders: a chart review. *BMC Pediatr*. 2005;5(1):48
 48. Zuckerman KE, Hill AP, Guion K, Voltolina L, Fombonne E. Overweight and obesity: prevalence and correlates in a large clinical sample of children with autism spectrum disorder. *J Autism Dev Disord*. 2014;44(7):1708–1719
 49. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*. 4th ed. Washington, DC: American Psychiatric Association; 2000
 50. Lord C, Risi S, Lambrecht L, et al. The autism diagnostic observation schedule-generic: a standard measure of social and communication deficits associated with the spectrum of autism. *J Autism Dev Disord*. 2000;30(3):205–223
 51. Gotham K, Risi S, Pickles A, Lord C. The Autism Diagnostic Observation Schedule: revised algorithms for improved diagnostic validity. *J Autism Dev Disord*. 2007;37(4):613–627
 52. Gotham K, Pickles A, Lord C. Standardizing ADOS scores for a measure of severity in autism spectrum disorders. *J Autism Dev Disord*. 2009;39(5):693–705
 53. Sparrow SS, Balla DA, Cicchetti DV. *Vineland Adaptive Behavior Scales*. 2nd ed. Circle Pines, MN: American Guidance Service; 2005
 54. Roid G. *Stanford–Binet Intelligence Scales*. 5th ed. Rolling Meadows, IL: Riverside Publishing; 2003
 55. Wechsler D. *Wechsler Intelligence Scale for Children*. 4th ed. San Antonio, TX: The Psychological Corporation; 2003
 56. Elliot C. *Differential Abilities Scale Manual*. 2nd ed. San Antonio, TX: Harcourt Assessment, Inc.; 2007
 57. Wechsler D. *Wechsler Preschool and Primary Scale of Intelligence*. 3rd ed. San Antonio, TX: The Psychological Corporation; 2002
 58. Wechsler D. *Wechsler Abbreviated Scale of Intelligence*. San Antonio, TX: Psychological Corporation; 1999
 59. Roid GM, Miller LJ. *Leiter International Performance Scale—Revised: Examiners Manual*. Wood Dale, IL: Stoelting Co.; 1997
 60. Mullen EM. *Mullen Scales of Early Learning*. Circle Pines, MN: American Guidance Service; 1995
 61. Owens JA, Spirito A, McGuinn M. The Children's Sleep Habits Questionnaire (CSHQ): psychometric properties of a survey instrument for school-aged children. *Sleep*. 2000;23(8):1043–1051
 62. Deprey L, Ozonoff S. Assessment of comorbid psychiatric conditions in autism spectrum disorders. In: Golstein S, Goldstein S, Naglieri JA, Ozonoff S, eds. *Assessment of Autism Spectrum Disorders*. New York, NY: The Guilford Press; 2009:290–317
 63. Achenbach TM, Rescorla L. *Manual for the ASEBA Preschool Forms & Profiles: An Integrated System of Multi-Informant Assessment*. Burlington, VT: ASEBA; 2000
 64. Achenbach TM, Rescorla L. *Manual for the ASEBA School-Age Forms & Profiles: An Integrated System of Multi-Informant Assessment*. Burlington, VT: ASEBA; 2001
 65. Lumley T. Survey: analysis of complex survey samples. R package version 3.28-2. 2012
 66. Lumley T. Analysis of complex survey samples. *J Stat Softw*. 2004;9(8):1–19
 67. Benjamini Y, Hochberg Y. On the adaptive control of the false discovery rate in multiple testing with independent statistics. *J Educ Behav Stat*. 2000;25(1):60–83
 68. Sterne JAC, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ*. 2009;338:b2393
 69. Stuart EA, Azur M, Frangakis C, Leaf P. Multiple imputation with large data sets: a case study of the Children's Mental Health Initiative. *Am J Epidemiol*. 2009;169(9):1133–1139
 70. Egan AM, Dreyer ML, Odar CC, Beckwith M, Garrison CB. Obesity in young children with autism spectrum disorders: prevalence and associated factors. *Child Obes*. 2013;9(2):125–131
 71. Braveman P. A health disparities perspective on obesity research. *Prev Chronic Dis*. 2009;6(3):A91
 72. Drewnowski A, Darmon N. The economics of obesity: dietary energy density and energy cost. *Am J Clin Nutr*. 2005;82(1 suppl):265S–273S
 73. Taveras EM, Gillman MW, Kleinman K, Rich-Edwards JW, Rifas-Shiman SL. Racial/ethnic differences in early-life risk factors for childhood obesity. *Pediatrics*. 2010;125(4):686–695
 74. Ho HH, Eaves LC, Peabody D. Nutrient intake and obesity in children with autism. *Focus Autism Other Dev Disabil*. 1997;12(3):187–192
 75. Pashankar DS, Loening-Baucke V. Increased prevalence of obesity in children with functional constipation evaluated in an academic medical center. *Pediatrics*. 2005;116(3). Available at: www.pediatrics.org/cgi/content/full/116/3/e377
 76. Teitelbaum JE, Sinha P, Micale M, Yeung S, Jaeger J. Obesity is related to multiple functional abdominal diseases. *J Pediatr*. 2009;154(3):444–446
 77. Gorrindo P, Williams KC, Lee EB, Walker LS, McGrew SG, Levitt P. Gastrointestinal dysfunction in autism: parental report, clinical evaluation, and associated factors. *Autism Res*. 2012;5(2):101–108
 78. Ahima RS, Lazar MA. Physiology. The health risk of obesity—better metrics imperative. *Science*. 2013;341(6148):856–858
 79. Prentice AM, Jebb SA. Beyond body mass index. *Obes Rev*. 2001;2(3):141–147
 80. Flegal KM, Ogden CL, Yanovski JA, et al. High adiposity and high body mass

- index-for-age in US children and adolescents overall and by race-ethnic group. *Am J Clin Nutr.* 2010;91(4):1020–1026
81. O'Brien M, Nader PR, Houts RM, et al. The ecology of childhood overweight: a 12-year longitudinal analysis. *Int J Obes.* 2007;31(9):1469–1478
82. Whiteley P, Dodou K, Todd L, Shattock P. Body mass index of children from the United Kingdom diagnosed with pervasive developmental disorders. *Pediatrics International.* 2004;46(5):531–533
83. Xiong N, Ji C, Li Y, He Z, Bo H, Zhao Y. The physical status of children with autism in China. *Res Dev Disabil.* 2009;30(1):70–76
84. Chen AY, Kim SE, Houtrow AJ, Newacheck PW. Prevalence of obesity among children with chronic conditions. *Obesity.* 2010;18(1):210–213
85. Rimmer JHJ, Yamaki KK, Lowry BMD, Wang EE, Vogel LCL. Obesity and obesity-related secondary conditions in adolescents with intellectual/developmental disabilities. *J Intellectual Disabil Res.* 2010;54(9):787–794
86. Hyman SL, Stewart PA, Schmidt B, et al. Nutrient intake from food in children with autism. *Pediatrics.* 2012;130 Suppl 2 (Supplement):S145–S153
87. Memari AH, Kordi R, Ziaee V, Mirfazeli FS, Setoodeh MS. Weight status in Iranian children with autism spectrum disorders: Investigation of underweight, overweight and obesity. *Research in Autism Spectrum Disorders.* 2012;6(1):234–239
88. Johnson CL, Paulose-Ram R, Ogden CL, et al. National health and nutrition examination survey: analytic guidelines, 1999–2010. *Vital Health Stat 2.* 2013; (161):1–24
89. van Buuren S, Groothuis-Oudshoorn K. MICE: Multivariate imputation by chained equations in R. *J Statistical Software.* 2011;45(3):1–67

Obesity and Autism

Alison Presmanes Hill, Katharine E. Zuckerman and Eric Fombonne
Pediatrics; originally published online November 2, 2015;
DOI: 10.1542/peds.2015-1437

Updated Information & Services	including high resolution figures, can be found at: /content/early/2015/10/28/peds.2015-1437
Supplementary Material	Supplementary material can be found at: /content/suppl/2015/10/28/peds.2015-1437.DCSupplemental.html
Subspecialty Collections	This article, along with others on similar topics, appears in the following collection(s): Developmental/Behavioral Pediatrics /cgi/collection/development:behavioral_issues_sub Autism/ASD /cgi/collection/autism:asd_sub Obesity /cgi/collection/obesity_new_sub
Permissions & Licensing	Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at: /site/misc/Permissions.xhtml
Reprints	Information about ordering reprints can be found online: /site/misc/reprints.xhtml

PEDIATRICS is the official journal of the American Academy of Pediatrics. A monthly publication, it has been published continuously since 1948. PEDIATRICS is owned, published, and trademarked by the American Academy of Pediatrics, 141 Northwest Point Boulevard, Elk Grove Village, Illinois, 60007. Copyright © 2015 by the American Academy of Pediatrics. All rights reserved. Print ISSN: 0031-4005. Online ISSN: 1098-4275.

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™



PEDIATRICS®

OFFICIAL JOURNAL OF THE AMERICAN ACADEMY OF PEDIATRICS

Obesity and Autism

Alison Presmanes Hill, Katharine E. Zuckerman and Eric Fombonne
Pediatrics; originally published online November 2, 2015;
DOI: 10.1542/peds.2015-1437

The online version of this article, along with updated information and services, is
located on the World Wide Web at:
[/content/early/2015/10/28/peds.2015-1437](http://content.early/2015/10/28/peds.2015-1437)

PEDIATRICS is the official journal of the American Academy of Pediatrics. A monthly publication, it has been published continuously since 1948. PEDIATRICS is owned, published, and trademarked by the American Academy of Pediatrics, 141 Northwest Point Boulevard, Elk Grove Village, Illinois, 60007. Copyright © 2015 by the American Academy of Pediatrics. All rights reserved. Print ISSN: 0031-4005. Online ISSN: 1098-4275.

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™

