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Differences in Body Mass Index (BMI) in Early Adolescents with Autism Spectrum Disorder Compared to Youth with Typical Development

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Abstract

Adolescence is a time of exceptional physical health juxtaposed against significant psychosocial and weight-related problems. The study included 241, 10-to-13-year-old youth with autism spectrum disorder (ASD, N=138) or typical development (TD, N=103). Standardized exams measured pubertal development, height (HT), weight (WT), heart rate (HR), blood pressure (BP) and Body Mass Index (BMI). Analysis of Variance showed no significant between-group differences for HT, WT, HR, or BP (all $p>0.05$). There was a significant difference in BMI-percentile between the groups ($F(1,234)=6.05$, $p=0.01$). Using hierarchical linear regression, significant predictors of BMI-percentile included diagnosis, pubertal stage and socioeconomic status. Pre-to-early pubescent children with ASD evidence higher BMI percentiles compared to youth with TD suggesting they may be at heightened risk for weight-related health concerns.

Keywords

autism; BMI; puberty; adolescence

The adolescent period presents a health paradox (Dahl, 2004; Forbes & Dahl, 2010); it is a time of exceptional physical health juxtaposed against a significant rise in mortality rates related to psychosocial (e.g., suicide, eating disorders) and risk-taking (e.g., accidents) behavior (CDC, 2010). The significant biobehavioral changes in cognitive, social, emotional

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Compliance with Ethical Standards
Disclosure of Potential Conflicts of Interest
The authors declare that they have no conflict of interest.

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

Informed Consent
Informed written consent and assent was obtained from all parents and study participants, respectively, prior to inclusion in the study.

and physical development during adolescence coincide with the onset and course of puberty (e.g., Chrousos, Torpy, & Gold, 1998; Spear, 2000; Steinberg, 2005). The morphological changes in physical state also give rise to psychological and social adjustments, in part, related to transformation in body image which in turn may contribute to mental health challenges (Graber, Lewinsohn, Seeley, & Brooks-Gunn, 1997; Waylen & Wolke, 2004).

Although the term *youth* is often synonymous with optimal health, it is becoming associated with weight-related concerns involving rising rates of overweight and obesity (Hales, Carroll, Fryar, & Ogden, 2018). According to the Centers for Disease Control (CDC) report from 2015–2016, the prevalence of obesity in the United States was 18.4% for children (6–11 years) and 20.6% for adolescents (12–19 years), both of which were higher than younger children (2–5 years, prevalence of 13.9%) (Hales et al., 2018). Adolescents who are overweight have higher rates of physical and medical problems related to pathology formerly considered adult diseases impacting multiple systems including cardiovascular, endocrine, gastrointestinal, pulmonary and musculoskeletal (Kumar & Kelly, 2017). In addition to the concomitant health concerns, adolescents with obesity have lower self-esteem (Strauss, 2000) and higher rates of mental health issues (Sawyer, Harchak, Wake, & Lynch, 2011).

Despite the recognition of the teen years being a time of remarkable change, considerably less is known about this period of time in youth with autism spectrum disorder (ASD). ASD is defined by difficulties in social communication and interaction, as well as intense restricted and repetitive patterns of interests and behaviors (APA, 2013). Comorbid physical symptoms are also common, such as gastrointestinal disorders or neurological complaints (e.g., Chaidez, Hansen, & Hertz-Picciotto, 2014; Reynolds & Malow, 2011). Nevertheless, ASD is primarily conceptualized as a psychosocial diagnosis, with substantially less attention paid to physical health status including weight.

Early research studying weight using body mass index (BMI) has primarily consisted of small sample sizes or retrospective reviews (Curtin, Jojic, & Bandini, 2014). However, a recent review and meta-analysis pooling studies from around the world estimated the prevalence of obesity in ASD to be 22.2% (Kahathuduwa et al., 2019). A recent study examined associations between weight status and ASD in the presence of comorbidities (Levy et al., 2019), showing that several medical conditions (e.g., asthma, endocrine and genetic disorders) were associated with overweight/obesity.

Age is a significant factor in the prevalence of obesity. Using data derived from the 2011–2012 National Survey of Children’s Health (NSCH), odds ratio analyses revealed that obesity in the ASD sample (N=925) relative to the non-ASD sample (N=42,852) increased significantly from 10 to 17 years of age (Must et al., 2017). Based on more recent 2016–2017 NSCH data, Healy, Aigner and Haegele (2019) corroborated earlier reports showing youth with ASD have significantly higher odds of being overweight (19.4%) or obese (23.05%) compared to the odds of youth with typical development (TD) being overweight (14.9%) or obese (15.91%). Utilizing the same NSCH data, McCoy and Morgan (2020) extended these findings by showing that as ASD symptom severity increased rates of overweight and obesity also increased whereas the amount of physical activity decreased compared to peers with TD, underscoring the need for interventions targeting increased activity and healthy lifestyles.

Indeed, adolescents with ASD may be particularly vulnerable to the development of obesity due to their behavioral, physical and psychosocial difficulties (Curtin, Anderson, Must, & Bandini, 2010). Other studies corroborate the notion that elevated rates of overweight and obesity are especially prevalent during adolescence (Hill, Zuckerman, & Fombonne, 2015) and have been associated with health conditions, affective problems and sleep disturbance (e.g. Hill et al., 2015; Phillips et al., 2014; Zuckerman, Hill, Guion, Voltolina, & Fombonne, 2014). In addition to age, Must and colleagues (2017) found sex differences, as the prevalence of obesity increased over adolescence for males, yet decreased for females with ASD. In addition to age and sex, the increased risk for developing obesity in ASD children has been shown to be moderated by race and living in the United States (Anderson & Whitaker, 2009; Eagle et al., 2012). While developmental variables such as age and sex have been associated with BMI and ASD, few studies have attempted to look explicitly at the impact of pubertal development on BMI.

The purpose of the current study was to cross-sectionally examine the general health status (using anthropometric measures) of a large sample of 241 pre-to-early pubescent 10-year, 0-month-to-13-year, 11-month old, well-characterized children with ASD (N = 138) or typical development (TD, N = 103) participating in a longitudinal study of pubertal development. Due to the rising concerns of overweight and obesity especially during adolescence, we focused on BMI and the relationship to pubertal status. It was also hypothesized that general health factors (e.g., height (HT), heart rate (HR), blood pressure (BP)) would be comparable between youth with ASD compared to same-age youth with TD. Consistent with previous literature (e.g. Curtin et al., 2010; Curtin et al., 2014; Hill et al., 2015), youth with ASD were hypothesized to show higher BMI relative to youth with TD. Moreover, beyond ASD diagnosis, potential effects on BMI, namely, pubertal status, medication-use, race and socioeconomic status (SES), were explored.

Methods

Participants

The data for this study were collected as part of a longitudinal study on pubertal development and stress (Corbett, 2017). The current paper includes data from the initial year of enrollment when the children were between 10-years, 0-months, to 13-years, 11-months of age. Participants were recruited from a broad community sample in the southern United States covering a 200-mile radius that targeted affiliated medical and health-related network services, well-check and diagnostic clinics, research registries, regional autism/disability organizations, schools and social media platforms. The racial and ethnic characterization of the sample included 7.9% African-American, 83.0% Caucasian, 0.4% Asian, and 8.7% Mixed. Inclusion in the study required participants to have an intelligence quotient (IQ) score ≥ 70 due to some of the task demands of the psychological and social protocols used in the longitudinal study (Corbett, 2017). Exclusion criteria were current use of medications known to alter the Hypothalamic Pituitary Adrenal (HPA) axis (e.g., corticosteroids; see (Granger, Hibel, Fortunato, & Kapelewski, 2009)) or HPG axis (e.g., growth hormone) or a diagnosed neurological (e.g., seizures) or medical condition known to impact pubertal development (e.g., Cushing's Disease). There were 24 participants not enrolled who were identified at phone screen as being ineligible (i.e., lower IQ, insufficient language level, extreme aggression). Demographic information for each group is presented in Table 1.

The diagnosis of ASD was based on the Diagnostic and Statistical Manual of Mental Disorders-5 (APA, 2013) and established by: (1) a previous diagnosis by a psychologist, psychiatrist or behavioral pediatrician with autism expertise; (2) current clinical judgment by a licensed clinical psychologist (BAC), and (3) corroborated by the Autism Diagnostic Observation Schedule (ADOS-2; Lord et al., 2012), administered by research-reliable (i.e., achieved national research reliability on the ADOS) personnel. The same team of individuals participated in the confirmatory diagnostic procedures. The approach is consistent with standards set by the NICHD/NIDCD Collaborative Programs of Excellence in Autism (Lainhart et al., 2006). The study was carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). The Vanderbilt Institutional Review Board approved the study. Prior to inclusion in the study, informed written consent and verbal assent was obtained from all parents and child participants, respectively.

Procedures

The following study procedures were conducted during a single visit.

Diagnostic Procedures—*Autism Diagnostic Observation Schedule-Second Edition* (ADOS-2; Lord et al., 2012) is a semi-structured, play and interview-based instrument used to support the diagnosis of ASD. The ADOS was administered by research-reliable personnel. A score of 7 or above on Module 3 (fluent speech) was required for inclusion in the study.

Social Communication Questionnaire – Lifetime version (SCQ; Rutter, Bailey, & Lord, 2003) is a screening instrument for the assessment of ASD symptoms. The SCQ was administered to both groups. A score of 15 is suggestive of ASD. Youth with TD with a score ≥ 10 were excluded from the study.

Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II; Wechsler, 2011) is a measure of cognitive ability used to obtain an estimate of the child's current intellectual functioning (IQ ≥ 70 required).

Exam Procedures and Dependent Measures—Standardized physical exams were conducted for pubertal staging and to measure HT, WT, HR and BP.

Pubertal Physical Exam: A comprehensive evaluation of pubertal development was collected based on parent-report, self-report and physical exam, showing the exam to be superior and more precise for estimating pubertal stage (Corbett, Muscatello, Tanguturi, McGinn, & Ioannou, 2019). Specifically, the concordance rate between the gold-standard physical exam and the self-assessments by the youth with ASD or TD ranged from slight-to-fair (κ = .17–.32) and the parent-report ranged from slight-to-moderate (κ = .21–.44). Therefore, to be as accurate as possible with pubertal stage, only the exam values were included in the current study. Consistent with Tanner's original exam, it consisted of a brief, standardized visual inspection to ascertain two measures with 5 stages for Genitals (G1-G5 for males) and Breasts (B1-B5 for females) (GB stage) and Pubic hair (P1-P5 for both sexes) (PH stage) (Marshal & Tanner, 1970; Marshall & Tanner, 1969). The exam was conducted by trained, licensed study physicians. A male physician conducted the majority of the exams and two female study physicians provided same-sex exams as requested. Physicians were blinded to parental and self-reports.

Height (HT) & Weight (WT): Height and weight were measured once using a calibrated stand-on Health-o-meter TM Professional 499KL Waist High Digital Scale with Height Rod (Hogentogler & Co., MD, USA). Height was measured to the nearest inch and weight was measured to the nearest 0.1 lb. Children were weighed and measured in light clothing.

Body Mass Index (BMI): While BMI-for-age percentile is not a diagnostic tool, it is used to measure size and growth patterns. BMI may also be considered a proxy for the percentage of body fat and is a fair predictor of cardiovascular risk (Buchan et al., 2017). BMI was calculated using the standard formula (lb/in^2) x 703 for use with the CDC growth charts for children and adolescents (2 through 19 years; https://www.cdc.gov/healthyweight/bmi/calculator.html). Percentiles and z-scores were calculated according to CDC growth charts based on sex and age. We used the Centers for Disease Control (CDC) recommended percentile categories: underweight ($< 5^{th}$), healthy weight (5^{th} to $< 85^{th}$), overweight (85^{th} to $< 95^{th}$) and obese ($\geq 95^{th}$) percentile. Z-scores were used in regression analyses.

Blood pressure (BP) & Heart Rate (HR): BP and HR were measured once on the child's left arm in sitting position using a Sure Signs VS4 digital vital signs monitor (Koninklijke Philips, USA) using an appropriate age/size specific BP cuff.

Statistical Analyses

All analyses were conducted using SPSS software (version 27; IBM SPSS Statistics, IBM Corporation). For statistical analysis of BMI, age- and sex-adjusted Z-scores and percentiles were calculated based on the 2000 CDC growth charts (Kuczmarski et al., 2002).

Analysis of variance (ANOVAs) were used to compare health indices across the groups. For any variables that showed significant differences between the groups, within-group comparisons were conducted. Hierarchal regression assessed the contributions of pubertal stage (penis/breast, pubic hair), medication use, race and SES (i.e., parent education) interactions in predicting significant between-group differences (i.e., BMI).

Results

The total sample included 241 pre-to-early pubescent adolescents between 10.00 to 13.92 years of age, 159 males and 82 females, 138 with ASD (mean age = 11.42 years) and 103 with TD (mean age = 11.73 years). Five participants (1 TD male, 2 ASD males, 2 ASD females) did not complete the physical exam and thus did not have BMI data. In the ASD group, there were 102 males and 36 females, and in the TD group, there were 57 males and 46 females.

Regarding race, Pearson Chi square revealed significant differences between the groups (χ^2 (3) = 9.54, $p = 0.01$); specifically, the proportion of White, Black and Mixed race was 0.87, 0.02 and 0.11 for ASD and 0.81, 0.12 and 0.07 for TD groups, respectively.

ANOVAs revealed no statistically significant differences between the groups based on HT, WT, or BP (all $p > 0.05$; see Table 1). However, there was a significant difference in BMI percentile ($F(1,234) = 6.053$, $p = 0.015$). On average, the BMI percentile for ASD was mean = 65.54 (SD = 31.15) compared to mean = 55.43 (SD = 31.29) for TD. Regarding BMI categories (underweight, normal weight, overweight and obese), group differences in BMI categories were notable especially in the obese category (e.g., obese = 27.9% ASD vs. 16.0% TD) (see Table 2) but overall did not reach statistical significance (χ^2 (3) = 6.312, $p = 0.097$). However, the linear-by-linear association test used for larger-than-2×2 table, was significant (χ^2 (1) = 4.387, $p = 0.036$). Subsequently, the groups were compared based on sex for BMI status; there were significant differences for males ($F(1,154) = 6.243$, $p = 0.014$), such that ASD males exhibited higher BMI percentile, yet there was no difference for females ($p > 0.05$).

There were also significant differences between the ASD (90/138) and TD (18/103) groups based on medication use (χ^2 (1) = 54.357, $p < 0.001$). Notably, 10 participants in the ASD group were on medications with risk for weight gain (8 on atypical antipsychotics—5 risperidone, 2 aripiprazole, and 1 quetiapine—and 2 on mirtazapine, an atypical antidepressant) while none of the participants in the TD group were taking medications with risk for weight gain. As a follow-up analysis, we removed subjects taking the aforementioned medications who completed the physical exam and reran the analyses examining BMI percentile. The results were still significant ($F(1,225) = 4.98$, $p = 0.03$).

A series of hierarchical regression analyses were run to identify predictors of BMI status (using z-scores), which included diagnosis, pubertal development (GB and PH stage), medication, race and SES. Full regression results are presented in Table 3. In the initial model, the main effect for diagnosis was significant in predicting BMI z-scores. After accounting for the effects of diagnosis, GB stage significantly accounted for an additional 3.8% of the model variance. Similarly, a separate model of PH stage, after accounting for diagnosis, significantly predicted BMI z-scores, contributing 7.6% of the model variance.

To model the effects of race and SES, race was added as a predictor to the initial base model of diagnosis only (Model 1). Race did not significantly contribute beyond diagnosis; however, in Model 3, SES based on parental education was significant, predicting 1.8% of the variance (see Table 3). In a final model, main effects of medication did not contribute to BMI z-scores ($\Delta R^2 = 0.009$, $\Delta F(1,233) = 2.27$, $p = 0.133$).

Discussion

The purpose of this study was to cross-sectionally examine BMI and general health status of a large sample of 241 pre-to-early pubescent 10-to-13-year-old, well-characterized youth with ASD or TD. It was hypothesized that youth in both groups would exhibit comparable general health status as reflected in their cardiac functioning (HR, BP) and physical characteristics (HT, WT). However, it was hypothesized that youth with ASD would show higher BMI relative to youth with TD.

The cardiac indices of HR and BP were similar across the groups, consistent with a study of school age children with and without ASD (Bricout, Pace, Dumortier, Favre-Juvin, & Guinot, 2018). Prior research on baseline HR and ASD has been rather mixed, with studies reporting elevated (Bal et al., 2010; Kushki, Brian, Dupuis, & Anagnostou, 2014), lower (Pace & Bricout, 2015) or no baseline differences (Bricout et al., 2018). Therefore, further research may be needed to understand these discrepancies and to identify children who may be at increased risk of subclinical cardiovascular disease (Croen et al., 2015; Heffernan et al., 2018; Shedlock et al., 2016; Tyler, Schramm, Karafa, Tang, & Jain, 2011). Despite the potential clinical implications of identifying cardiovascular risks in youth with ASD, clinical examination of autonomic functioning and overall heart health in ASD is relatively scarce. The majority of research focuses on the relationship between cardiovascular regulation to social disengagement, anxiety and related behaviors (e.g. Benevides & Lane, 2013; Kushki et al., 2014; Porges, 2007; Porges et al., 2007). For example, many youth with ASD show blunted HR reactivity or heart rate variability (HRV) to public speaking (Edmiston, Blain, & Corbett, 2017; Hollocks, Howlin, Papadopoulos, Khondoker, & Simonoff, 2014; Jansen, Gispen-de Wied, van der Gaag, & van Engeland, 2003; Kushki et al., 2014), which is further associated with anxiety (Hollocks et al., 2014; Kushki et al., 2014). While the association between autonomic dysfunction, social functioning and anxiety is important to consider, these studies do little to inform on the global health of the cardiovascular system.

In regards to height and weight, there were no significant differences between the groups, which confirmed the prediction, and values generally fell within the broad average range for both groups. Regarding weight, previous research has reported that children with ASD, when compared to youth with TD, often show higher average weight (Matheson & Douglas, 2017). However, BMI is frequently used to measure size and growth patterns and is considered a proxy for the percentage of body fat (Buchan et al., 2017). As predicted, significant differences were observed between the groups such that children with ASD had higher BMI percentiles compared to same-age peers with TD. The results are consistent with previous research showing elevated BMI in children with ASD when compared to youth with TD. Whiteley and colleagues (2004) found that nearly a third of the children in their study with pervasive developmental disorder had BMI scores falling outside the healthy weight range.

With regards to BMI categories, the current sample of youth with ASD showed 14.0% were classified as being overweight and 27.9% classified as obese compared to the TD group in which 12.0% were overweight and 16% were obese. Thus, while the overweight estimates were similar, a much higher percentage of youth with ASD were classified as obese. Previous research has reported similarly high prevalence rates of children with ASD being overweight ranging from 18% to 42% and obese ranging from 10% to 30.4% (Criado et al., 2018; Curtin et al., 2010; Whiteley et al., 2004; Zuckerman et al., 2014). For example, Criado et al. reported that 42.4% of their sample were classified as overweight and 21.4% classified as obese, a stark contrast to the TD controls of which the classification was 26.1% overweight and 12.0% obese (Criado et al., 2018). Granich et al. (2016) found that youth with ASD showed similar profiles with 35.1% of the sample classified as overweight and 29.9% classified as obese. Recently, Healy et al. (2019) showed the rates of overweight and obesity to be 19.4% and 23% in youth with ASD compared to 14.9% and 15.91% in youth with TD, respectively. Therefore, rates seem largely consistent and stable overtime.

Sex differences across the groups in the current sample were noted such that males with ASD had higher BMI compared to males with TD; yet, there were no significant differences in the females. These results may be similar to Must et al. (2017) that showed different BMI trajectories for males (increased over time) and females (decreased over time) with ASD.

Age is also a significant factor in the prevalence of obesity. As noted, Must et al. (2017) found increasing odds of obesity in youth with ASD relative to youth without ASD between 10 to 17 years of age. Rates of overweight and obesity are particularly high during adolescence and linked to a variety of physical and mental health conditions (e.g. Hill et al., 2015; Phillips et al., 2014; Zuckerman et al., 2014). In contrast, a recent study analyzing developmental progress of Brazilian children with ASD showed reductions in weight during adolescence (Toscano, Ferreira, Gaspar, & Carvalho, 2018).

The prevalence of overweight and obesity in adolescents with autism may be particularly problematic due to the behavioral, physical and psychosocial difficulties they experience (Curtin et al., 2010; Hill et al., 2015). Current findings showed BMI percentile was partially explained by pubertal development suggesting an upward trend in unhealthy weight as children enter and move through puberty. While the sample only included children in pre- and early pubertal stages, it will be essential to determine if BMI status changes with maturational development. Fortunately, this sample is part of a longitudinal study with annual visits, which will allow the study of prospective changes in BMI and health status over the course of pubertal development in both groups.

Of the various risk factors contributing to obesity in individuals with ASD, the one best understood is the use of newer antipsychotic medication (Curtin et al., 2014). There is a high occurrence of psychotropic medication use in children with ASD, with estimates as high as 60% in certain samples (Siegel & Beaulieu, 2012). Two newer (second generation) antipsychotics (risperidone and aripiprazole) are the only FDA-approved medications (for irritability) for children with ASD, and they have been shown to significantly increase weight, likely due to increased appetite (Curtin et al., 2014). Other medications, including mood stabilizers, antiepileptics and antidepressants, have mixed associations with weight, as some studies have shown increased risk (Shedlock et al., 2016) while others show no associations (Broder-Fingert, Brazauskas, Lindgren, Iannuzzi, & Van Cleave, 2014).

Not surprisingly, there were significant differences between the ASD and TD groups based on medication use. Specifically, 67.6% of the ASD and 17.5% of the TD group were on medications. Ten participants in the ASD group were on medications with risk for weight gain whereas none of the participants in the TD group were taking medications with risk for weight gain. However, BMI percentile findings did not change when these 10 individuals were removed from the analyses.

One of the leading contributing factors to increased weight and BMI is reduced activity level and increased sedentary behavior, an unfortunate trend in current society (Curtin et al., 2014). Children with ASD participate less in physical activity than children with TD (McCoy, Jakicic, & Gibbs, 2016). Moreover, it has been shown that as ASD symptom severity increases physical activity decreases (McCoy & Morgan, 2020). A review of 35 studies revealed a negative trend showing that as children with ASD age, they engage in less physical activity (Jones et al., 2017). However, young children with ASD engage in comparable moderate-to-vigorous physical activity as same-age children with TD (Thomas, Hinkley, Barnett, May, & Rinehart, 2019). While it is unknown when and why deleterious changes occur over development, the findings suggest that early and continuous interventions targeted at moderate-to-vigorous physical activity may be far-reaching in maintaining a healthy standard of living in children with ASD and their families.

Most U.S. adolescents do not meet recommended daily exercise (i.e., 60+ minutes) or consume the appropriate nutrition (5+ servings of fruits and vegetables) per day (Iannotti & Wang, 2013). Eating behavior and physical activity track together and have a strong habitual pattern over development (Biddle, Pearson, Ross, & Braithwaite, 2010; Iannotti & Wang, 2013); therefore, establishing a healthy lifestyle early-on is key. Among the secular trends that lead to diminished moderate-to-vigorous physical activity include increased leisure-time, computer use and television viewing (Nelson, Neumark-Sztainer, Hannan, Sirard, & Story, 2006). Such sedentary habits in youth are associated with increases in BMI especially at the upper end of the distribution (i.e., overweight and obese) (Mitchell, Rodriguez, Schmitz, & Audrain-McGovern, 2013).

Several barriers to formal and informal physical activity in ASD have been identified to include social and behavioral challenges (Must, Phillips, Curtin, & Bandini, 2015). Mazurek and colleagues (2012) underscored this trend showing youth with ASD report a 41.4% higher prevalence of electronic game use compared to other groups and nearly 64.2% spend most of their free time engaged in solitary screen-based media use.

Another potential barrier to healthy weight and BMI status is poor nutritional intake. Participants with ASD consume significantly higher amounts of juice and sweetened beverages and lower amounts of vegetables compared to peers with TD (Evans et al., 2012). Heathy eating in ASD is a notable problem presumably due to food sensitivity and selectivity related to taste, texture and variety (Cermak, Curtin, & Bandini, 2010). Children with ASD show greater food refusal and a more limited food repertoire compared to same-age peers (Bandini et al., 2010).

The clinical implications from the current study showing increased BMI percentiles in youth with ASD which are associated with diagnosis, pubertal stage and SES, underscore the need to identify targeted programs to reduce unhealthy weight status while promoting healthy life styles. The results suggest a need for enhanced awareness of the developmental changes associated with puberty and the tendency of youth with ASD to decrease activity during adolescence. Importantly, higher BMI can contribute to advanced pubertal onset in youth with ASD that may have psychological, social and physical consequences (Corbett, Vandekar, Muscatello, & Tanguturi, in press). Establishing and maintaining better nutritional and activity habits during and beyond childhood are foundational to a lifetime of healthy living (Biddle et al., 2010; Iannotti & Wang, 2013). The finding that BMI was associated with SES underscores the fundamental need of youth with ASD to have access to nutritional foods. Identifying individual barriers to more balanced and appropriate nutrition is essential (Iannotti & Wang, 2013). Finally, promoting and developing opportunities and interventions targeting enhanced physical activities for adolescents with ASD (McCoy & Morgan, 2020) are needed to improve healthy weight outcomes.

Strengths and Limitations

The primary aim of the current study was to examine BMI and general health status in pre- to early pubescent children with ASD compared to a group of same-age peers. Strengths include the rigorous assessment of a well-characterized large group of youth with ASD based on gold standard diagnostic, pubertal assessment, and physical exam measures. Despite these strengths, there are limitations. Although activity level and nutritional intake have been shown to be relevant for BMI, these data were not collected. Future studies will benefit from the inclusion of such measures. Additionally, due to the lack of normative differences between males and females with ASD, next steps will include more careful tracking of sex similarities and differences as this sample develops over puberty.

Conclusions

The current findings underscore the growing trend within and beyond autism of an increasing number of young children who are classified as overweight or obese, which demands clinical and research focus. These results suggest that children with ASD may be at heightened risk for weight-related health concerns. If elevated BMI levels are detected, underlying contributing factors to include diet, physical activity, and family history must be considered to improve health outcomes for youth with ASD.

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Table 1.

Demographics

	ASD (n=138)	TD (n=103)	t	*p*
	M (*SD*)	M (*SD*)		
Age	11.42 (1.03)	11.73 (1.21)	2.08	0.04
IQ	101.14 (20.86)	117.03 (13.92)	7.07	<0.001
SCQ	17.38 (8.32)	2.70 (2.50)	−19.57	<0.001
ADOS Total	12.58 (4.57)	--	--	--
SES	15.68 (2.98)	17.34 (2.17)	4.70	<0.001
Height	59.35 (4.19)	59.86 (3.90)	0.95	0.34
Weight	108.77 (41.30)	102.51 (34.27)	−1.24	0.22
Heart Rate	75.60 (15.95)	75.34 (16.24)	−0.11	0.91
Systolic BP	109.70 (10.76)	109.67 (11.98)	−0.02	0.98
Diastolic BP	64.35 (8.30)	63.53 (8.49)	0.67	0.51
BMI (Percentile)	65.54 (31.15)	55.43 (31.29)	−2.46	0.01

ADOS, Autism Diagnostic Observation Schedule; BMI, Body Mass Index; BP, Blood Pressure; SCQ, Social Communication Questionnaire; SES, Socioeconomic Status. BMI Percentile defined as age- and sex-adjusted percentile according to CDC guidelines (https://www.cdc.gov/healthyweight/bmi/calculator.html).

Table 2.

Percentage of ASD and TD participants falling into each BMI Category.

BMI Category	TD (N = 100)	ASD (N = 136)	Total
Underweight	3.0% (n=3)	4.5% (n=6)	3.8% (n=9)
Healthy Weight	69.0% (n=69)	53.8% (n=73)	60.2% (n=142)
Overweight	12.0% (n=12)	13.6% (n=19)	13.1% (n=31)
Obese	16.0% (n=16)	28.0% (n=38)	22.9% (n=54)
Total	100%	100%	100%

Note: Underweight, $<5^{th}$ percentile; Healthy Weight, 5^{th} to $<85^{th}$ percentile; Overweight, 85^{th} to $<95^{th}$ percentile; Obese, $\geq 95^{th}$ percentile

Table 3.

Regression Models Predicting BMI Z-Scores.

	Model 1		Model 2						Model 3	
			2a		2b		2c			
Variable	β	*p*	β	*p*	β	*p*	β	*p*	β	*p*
Diagnosis	0.15	0.02	0.14	0.02	0.15	0.01	0.15	0.02	0.11	0.10
GB Stage	--	--	0.20	0.002	--	--	--	--	--	--
PH Stage	--	--	--	--	0.28	<0.001	--	--	--	--
Race	--	--	--	--	--	--	0.08	0.25	0.06	0.32
SES	--	--	--	--	--	--	--	--	−0.14	0.04

	Model 1	Model 2a	Model 2b	Model 2c	Model 3
R^2	0.02	0.06	0.10	0.03	0.05
ΔR^2	**0.02** *	**0.04** *	**0.08** *	0.01	**0.02** *
$\Delta F_{(df)}$	**$5.44_{(1,233)}$** *	**$9.47_{(1,232)}$** *	**$19.66_{(1,232)}$** *	$1.34_{(1,226)}$	**$4.13_{(1,225)}$** *

GB, Genital/Breast; PH, Pubic Hair; SES, Socioeconomic Status

* *p*−value < 0.05