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Exploring Differences in Physical Health in Young Children With and Without ADHD

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Abstract

Objective: To assess differences in child physical health outcomes and metrices associated with obesity in a sample of predominantly Hispanic/Latinx young children with and without attention-deficit/hyperactivity disorder (ADHD).

Methods: Participants included 127 children diagnosed with ADHD and 96 typically developing (TD) children between 4 and 7 years of age. Objective measures of children's body composition, fitness, and physical activity were conducted. Parents of children completed food recalls to assess their child's dietary intake, diet quality was calculated based on the Healthy Eating Index-2015, and parents completed a survey about their family's health habits.

Results: Logistic regression revealed that those with ADHD were more likely to be classified as having an overweight or obese (Ov/O) body mass index (BMI). Linear regression analyses indicated that children with ADHD performed worse on a fitness test and consumed more calories relative to TD children. Moderation analyses indicated that sex differences in steps were prominent in our TD sample, but not among those with ADHD.

Conclusions: Young children with ADHD are at greater risk for having an Ov/O BMI, being less fit, and eating a greater intake of calories compared to TD children.

Keywords: attention, hyperactivity, and ADHD; health behavior; obesity and weight management; preschool children; nutrition; school-age children.

Introduction

The United States' prevalence rate of attention-deficit/hyperactivity disorder (ADHD) in children is about 9.4% (Danielson et al., 2018). ADHD is defined by elevated levels of inattention and/or hyperactivity and impulsivity (American Psychiatric Association, 2013). Clinically significant levels of these symptoms can impair social, academic, and occupational functioning (Nigg, 2013). Recent research has identified associations between physical health issues, obesity, and ADHD, even among children (Landes & London, 2021). Some of the physical health issues that ADHD is associated with, including obesity, may be due to health behaviors such as engaging in less physical activity (PA) and poor diet and nutrition (Harvey et al., 2009; Holtkamp et al., 2004; Waring & Lapane, 2008). However, disparities in PA, nutrition, and body composition among young children with and without ADHD have not been thoroughly explored. The current study focuses on a behavioral approach to studying physical health disparities among young children with and without ADHD in a predominantly Hispanic/Latinx sample. Identifying which physical health indices are most impaired in those with ADHD will be important for developing physical health interventions.

Pediatric Obesity

Youth with ADHD are at a higher risk for having an overweight/obese (Ov/O) body mass index (BMI) status compared to their typically developing (TD) counterparts (Cortese et al., 2016; Hales et al., 2017; Nigg et al., 2016). Older children with ADHD, especially girls, are more likely to have obese BMIs, and longitudinal evidence suggests that having ADHD puts one at risk for developing obesity throughout their lifetime (Nigg et al., 2016). What remains unclear is the extent to which the link between ADHD and risk for obesity can be identified in *early childhood*. Such early identification is important for intervention efforts given the stability of obesity (Singh et al., 2008).

Pediatric obesity can be conceptualized through the developmental framework of the Ecological Systems Theory (EST) (Bronfenbrenner et al., 1998; Davison & Birch, 2001). Much of the current literature focuses on societal (i.e., obesogenic environment; Swinburn et al., 1999) and parental correlates of pediatric obesity. Specifically, regarding pediatric obesity, parents have been referred to as "agents of change" given that they have significant control over their child's fitness development, engagement in PA, and nutritional intake (Golan, 2006; Pugliese & Tinsley, 2007; Sallis et al., 1988; Vilhjalmsson & Thorlindsson, 1998; Yee et al., 2017). While there are many parental and societal factors that contribute to obesity, the current paper focuses on *child risk factors*, specifically the link between ADHD and PA, including fitness, and nutrition.

Theoretically, the link between ADHD and obesity has been hypothesized to be due to shared neurobiological underpinnings (i.e., deficits in reward sensitivity and/or executive functioning) and/or related to how ADHD symptoms over

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time contribute to poor health behaviors (i.e., overeating) (Cortese et al., 2008). Dysregulated dopaminergic neurotransmission has been shown to be an overlapping factor of ADHD and obesity (Franco, et al., 2021). For example, children who are highly impulsive, or reward-sensitive, consume significantly more calories than their less reward-sensitive counterparts (Guerrieri et al., 2008). Blood pressure dysregulation has also been suggested as a shared mechanism linking the cardiovascular risk present among those with ADHD and low levels of PA and fitness (Garcia-Argibay et al., 2022; Kollins & Adcock, 2014). Finding significant links between ADHD and obesity and obesity-related behaviors in early childhood could provide further evidence for theories suggesting an overlap in such neurobiological underpinnings.

Physical Activity

Despite hyperactivity being a prominent symptom for many children diagnosed with ADHD, preliminary work suggests that children with ADHD engage in less PA and have worse cardiovascular fitness (Bundgaard et al., 2018; Muntaner-Mas et al., 2021; Tandon et al., 2019). Importantly, prior studies did not compare how PA and fitness differ between young TD children and those with ADHD. Sex also plays a role in PA: boys are more likely to engage in more PA and have higher fitness levels compared to girls (Breslin et al., 2012; Marta et al., 2012). Despite sex differences in ADHD diagnoses (Gaub & Carlson, 1997; Gershon & Gershon, 2002, Loyer Carbonneau et al., 2021) and in BMI status, little is known about how PA and fitness differ by both ADHD diagnostic status and sex among young children.

Nutrition

Similar to PA and fitness, those with ADHD have been shown to deviate from nutritional guidelines. ADHD behaviors and diagnostic status have been associated with overconsumption among adolescents (i.e., binging behaviors) (Sonneville et al., 2015; Villa et al., 2023), as well as more frequent snacking, greater consumption of added sugars, and lower consumption of fruits and vegetables among boys ages 6–10 (Ptacek et al., 2014). Sex differences in nutrition have also been identified. Despite consuming similar caloric quantities, boys exhibit more sedentary snacking and greater consumption of fast food while girls demonstrate greater adherence to nutritional quality guidelines (e.g., consuming more fruits and vegetables) (Fernandez et al., 2016; Gubbels et al., 2012). Overall, adolescents and children with ADHD, especially boys, are at risk of not meeting nutritional guidelines and ending up with a caloric surplus, further putting them at risk for developing obesity.

Hispanic/Latinx Population

Similar to ADHD diagnostic status and sex, ethnicity has a significant effect on rates of obesity (Caprio et al., 2008). The Hispanic/Latinx population is of particular relevance due to their population growth within the United States and greater risk of having an Ov/O BMI status (Fryar et al., 2020; Mather, 2016). However, the current literature has yet to identify physical health behaviors that contribute to pediatric obesity in Hispanic/Latinx populations. Furthermore, less is known about how ADHD is related to physical health behaviors within a predominantly Hispanic/Latinx sample. Given that young children of Hispanic/Latinx decent are more likely to be underdiagnosed with ADHD (Zablotsky & Alford, 2020) and are more likely to have an overweight/obese BMI, it is even more important that research investigates the associations between ADHD and physical health behaviors among a well-represented sample of Hispanic/Latinx youth in early childhood.

Current Study

The current study is the first of its kind to compare *young* children with and without ADHD on a variety of individual-level risk factors for pediatric obesity including body composition, PA, and nutrition. This study's geographical location also provided an advantage in terms of including a predominantly Hispanic/Latinx sample that has been underrepresented in previous ADHD and health behavior studies. We hypothesize that children with ADHD will have higher BMIs, higher rates of Ov/O BMIs, and higher body fat percentages and that these associations will be more prominent in female children. Conversely, we hypothesize that those with ADHD will engage in less PA and have lower levels of fitness compared to TD children. Finally, we hypothesize that children with ADHD will have worse average nutritional quality and will consume more calories compared to TD children.

Methods

Participants

The study was conducted at a university in the southeastern United States with a large Hispanic/Latinx population as part of a larger clinical intervention study for ADHD. Participants for this study included 223 children ages 4–7 years old (Mean age = 5.48, *SD* = .74). Participant demographics are presented in Table I. The clinic that housed the current study has extensive relationships with the local public-school districts and primary care and specialty physicians which facilitates ample recruitment opportunities. Both ADHD and TD participants were initially recruited from local schools and mental health agencies via brochures, open houses, and online ads. For the ADHD sample, inclusion criteria consisted of the following: endorsed clinically significant levels of ADHD symptoms (at least six symptoms of either Inattention or Hyperactivity/Impulsivity according to the Diagnostic and Statistical Manual of Mental Disorders Fifth Edition (DSM 5) or a previous diagnosis of ADHD), indicated that the child is currently displaying clinically significant academic, behavioral, and/or social impairments as measured by a score of at least 3 on a 7-point impairment rating scale (IRS; Fabiano et al., 2006) and were not taking any psychotropic medication. For the TD sample, inclusion criteria consisted of the following: the parent endorsed <4 ADHD symptoms, endorsed <4 Oppositional Defiant Disorder symptoms, and indicated no clinically significant impairment (score below 3 on the IRS). Then, the parents and children of both the ADHD and TD samples were invited to participate in an assessment to determine study eligibility. Participants were also required to be enrolled in school during the previous year, have an estimated IQ of at least 70, have no confirmed history of autism spectrum disorder and/or Autism Spectrum Rating Scales Short Form score below clinical cutoff T-score of 60 (Goldstein & Naglieri, 2009), and the ADHD group was required to attend an 8-week summer treatment program prior to the start of the next school year. During the initial assessment, ADHD diagnosis was assessed through a combination of parent structured interview (Computerized-Diagnostic Interview Schedule for Children; Shaffer et al., 2000) and parent

Table I. Demographic and Descriptive Statistics by ADHD Diagnostic Status

	ADHD ($n = 127$)		TD ($n = 96$)		Total ($n = 223$)	
	Cohort 1 ($n = 33$)	Cohort 2 ($n = 94$)	Cohort 1 ($n = 22$)	Cohort 2 ($n = 74$)	Cohort 1 ($n = 55$)	Cohort 2 ($n = 168$)
	M (*SD*)/*n* (%)		*M* (*SD*)/*n* (%)		*M* (*SD*)/*n* (%)	
Demographics						
Age	5.63 (0.87)	5.52 (0.61)	5.23 (0.86)	5.43 (0.79)	5.47 (0.88)	5.48 (0.69)
Male	24 (72.7%)	68 (72.3%)	18 (81.8%)*	37 (50.0%)*	42 (76.4%)	105 (62.5%)
Hispanic/Latinx	29 (87.9%)	80 (85.1%)	19 (86.4%)	54 (73.0%)	48 (87.3%)	134 (79.8%)
Race						
White	30 (90.9%)	90 (95.7%)	21 (95.5%)	67 (90.5%)	51 (92.7%)	157 (93.5%)
Black	2 (6.1%)	7 (7.4%)	0 (0%)	9 (12.2%)	2 (3.6%)	16 (9.5%)
Asian	1 (3.0%)	1 (1.1%)	2 (9.1%)	3 (4.1%)	3 (5.5%)	4 (2.4%)
American Indian	0 (0%)	1 (1.1%)	0 (0%)	3 (4.1%)	0 (0%)	4 (2.4%)
Maternal education						
HS degree or less	4 (12.9%)	4 (4.6%)	0 (0%)	1 (1.4%)	5 (9.1%)	5 (3.0%)
Some college	3 (9.7%)	16 (18.4%)	1 (4.5%)	5 (6.0%)	4 (7.3%)	21 (12.5%)
Associate degree	4 (12.9%)	13 (14.9%)	2 (9.1%)	5 (6.0%)	6 (10.9%)	18 (10.7%)
Bachelor's degree	9 (29.03%)	24 (27.6%)	5 (22.7%)	31 (43.1%)	14 (25.5%)	55 (32.7%)
Advanced degree	11 (35.5%)	30 (34.5%)	13 (59.1%)	30 (41.7%)	24 (43.6%)	60 (35.7%)
Marital status						
Single	3 (9.1%)	6 (6.4%)	0 (0%)	5 (6.8%)	3 (5.5%)	11 (6.5%)
Living with partner	4 (12.1%)	8 (8.5%)	1 (4.5%)	4 (5.4%)	5 (9.1%)	12 (7.1%)
Married	20 (60.6%)	67 (71.3%)	19 (96.4%)	59 (79.7%)	39 (70.9%)	126 (75.0%)
Separated	1 (3.0%)	2 (2.1%)	2 (9.1%)	2 (2.7%)	3 (5.5%)	4 (2.4%)
Divorced	5 (15.2%)	11 (11.7%)	0 (0%)	4 (5.4%)	5 (9.1%)	15 (8.9%)
Respondent						
Bio mother	29 (87.9%)	78 (83.0%)	19 (86.4%)	62 (83.8%)	48 (87.3%)	140 (83.3%)
Bio father	2 (6.1%)	11 (11.7%)	3 (13.6%)	11 (14.9%)	5 (9.1%)	22 (13.1%)
Adoptive mother	2 (6.1%)	3 (3.2%)	0 (0%)	1 (1.4%)	2 (3.6%)	4 (2.4%)
Adoptive father	0 (0%)	1 (1.1%)	0 (0%)	0 (0%)	0 (0%)	1 (0.6%)
Grandmother	0 (0%)	1 (1.1%)	0 (0%)	0 (0%)	0 (0%)	1 (0.6%)
Body composition						
BMI	17.22 (2.76)	16.67 (2.24)	16.44 (1.12)	16.39 (2.31)	16.91 (2.27)	16.55 (2.27)
BMI z-score	0.75 (1.29)	0.59 (1.10)	0.65 (0.72)	0.39 (1.16)	0.71 (1.09)	0.50 (1.13)
% body fat	22.77 (1.12)	22.87 (8.09)	22.74 (1.23)	22.42 (6.84)	22.76 (1.15)	22.67 (7.55)
Ov/O BMI	15 (45.5%)	32 (34.0%)	6 (27.3%)	18 (24.3%)	21 (38.2%)	50 (29.8%)
Physical activity						
Side jumps	14.94 (6.85)	15.90 (7.57)	17.92 (1.12)	18.32 (9.29)	16.13 (7.64)	16.97 (8.43)
Steps	9718.11 (3231.85)	9927.90 (2937.47)	10314.46 (2410.89)	9189.05 (2501.36)	9956.65 (2921.79)	9602.45 (2770.48)
EE	281.74 (77.21)	291.02 (76.33)	287.81 (39.20)	262.27 (83.92)	284.17 (64.33)	278.35 (80.79)
% Sed PA	70.26 (5.33)*	67.22 (4.76)*	69.22 (3.92)	69.36 (5.24)	69.84 (4.80)*	68.16 (5.08)*
% MV PA	10.24 (2.88)*	11.54 (2.71)*	10.68 (1.99)	10.33 (3.01)	10.41 (2.55)	11.01 (2.90)
FNPA-PA	2.65 (0.58)*	2.95 (0.66)*	3.01 (0.53)	3.09 (0.68)	2.79 (0.58)*	3.01 (0.67)*
Nutrition						
HEI	43.82 (8.10)*	49.51 (8.71)*	51.96 (10.48)	50.37 (11.70)	47.07 (9.89)	49.89 (10.12)
Calories	1697.72 (333.91)	1594.68 (318.36)	1616.03 (333.19)*	1412.37 (261.32)*	1665.05 (332.98)*	1514.37 (307.46)*

Note. *% Body fat* = percentage body fat; *% MVPA* = average percentage of day spent in moderate to vigorous physical activity; *% Sed PA* = average percentage of day spent in sedentary physical activity; *ADHD* = attention-deficit/hyperactivity disorder; *Bio* = biological; *BMI* = body mass index; *Calories* = average calories consumed daily (kcal); *Cohort 1* = Cohorts with incomplete data collection; *Cohort 2* = Cohorts with complete data collection; *EE* = average energy exerted per day; *FNPA-PA* = average score for the physical activity items on the FNPA; *HEI* = average overall Healthy Eating Index score; *HS* = high school; *Ov/O* = overweight or obese; *TD* = typically developing.

* $p < .05$ differences by cohort.

and teacher ratings of symptoms and impairment (Disruptive Behavior Disorders Rating Scale, IRS; Fabiano et al., 2006) as is recommended practice (Pelham et al., 2005). Dual PhD-level clinician review determined diagnosis and eligibility.

Study Design and Procedures

As part of the study's nutritional assessment, parents and children completed a 1-hour laboratory visit. Anthropometrics were collected from children and parents. Children completed a brief fitness test while parents completed their first dietary recall. Children were sent home wearing an accelerometer around their waist, and parents were instructed to ensure their child wore the accelerometer for the next week. Two additional dietary recalls were scheduled to be done via telephone within the next week. Parents also completed various questionnaires related to their child's behavior, PA, and nutrition. Parents were given $100 for their participation. An additional $50 was given upon returning the accelerometer and completing two additional dietary recalls. As children completed the tasks, they were given stickers and a toy prize at the end of the visit.

Measures

Demographics

Parents were asked to complete a demographics questionnaire regarding themselves and their child. Information collected included the child's date of birth, biological sex, race, ethnicity, and maternal education status.

Body Composition

Children's height was measured (without shoes) to the nearest .01 cm using a wall-mounted stadiometer (Seca, Columbia, MD). Participants were measured a total of three different times, and the average height measured was used for analyses. Mediana i35 Body Composition Analyzer provided information regarding overall weight (to the nearest .01 kg) and body composition (i.e., body fat percentage) via bioelectric impedance analysis. BMI, BMI percentile, and BMI z-score were calculated based on age and sex norms from the Centers for Disease Control and Prevention (CDC) and the National Center for Health Statistics. Body composition variables (i.e., BMI and body fat percentage) were examined as continuous measures while overweight/obese BMI status was examined as a categorical outcome per CDC percentile cutoff scores (Centers for Disease Control and Prevention, 2000).

Physical Activity

PA was measured using the triaxial accelerometer (Respironics Actical). The Actical was calibrated to the child's height and weight, and participants were instructed to wear the device on a belt at the waist for 7 days. Data were collected at 60 Hz in 15-second epochs and downloaded using the ActiReader and Actical Software Version 3.10. The Actical provided information regarding daily step count, energy expenditure (EE), percentage of the day spent in sedentary, moderate, and vigorous PA. Sedentary, moderate, and vigorous PA were categorized as exerting <0.04 kcals/min/kg, 0.04–0.099 kcals/min/kg, and ≥0.1 kcals/min/kg, respectively. The current study combined the moderate and vigorous PA categories into a single category: moderate to vigorous PA (MVPA) (Evenson et al., 2008). Previous studies that evaluated accelerometer wear with young children show that ≥3 days of wear and ≥10 hr of wear per day provides adequate data to achieve good intraclass correlations for percentage of the day in sedentary PA (ICC=.75) and percentage of the day in MVPA (ICC=.83) (Aadland & Johannessen, 2015). Steps, energy exerted (EE), and the percentages of the day spent in sedentary PA and in MVPA were then averaged across valid days of wear for each participant and examined as continuous variables.

Fitness

Children completed a side-to-side jump test as part of the Karlsruhe Motor Screening battery (KMS-3-6) (Bös et al., 2004). The fitness battery has been validated in young children ages 3–6 with the reliability of its test items ranging from $r = 0.8$ to $r = 0.9$ and validity ranging from .10 to .60 (Ayan et al., 2019). The number of side jumps in the 30-second period was used as a measurement of fitness with higher numbers indicating better fitness.

Family Nutrition and Physical Activity (FNPA)

Parents also completed the FNPA screening tool to evaluate their child's nutrition, PA, screen time, and sleep behaviors (Myers et al., 2002). The FNPA consists of 20 items on a 4-point Likert scale rating frequency of behaviors (1 = "Never/Almost Never", 4 = "Very Often/Always"). Items 14–18 ask about child and family PA (e.g., How often does your family provide opportunities for physical activity?). The current study used the average of items 14–18 as a parent rated index of PA ($\alpha = .82$).

Caloric Intake

A trained interviewer collected 24-hour food recalls (2 weekdays and 1 weekend day) with caregivers for their child. Food recalls were inputted into the Automated Self-Administered 24-hr (ASA24®) Dietary Assessment Tool where nutritional profiles were calculated and average daily caloric intake (kcals) was derived to measure dietary quantity (Krebs-Smith et al., 2018). Of note, consistent with prior work (Cecil et al., 2005; Krenitsky, 2005; Sylvetsky et al., 2019), all analyses involving average daily caloric intake covaried for children's weight to account for variation in daily energy intake requirements.

Healthy Eating Index

Data from the 24-hr food recalls were also used to examine diet quality via the Healthy Eating Index-2015 (HEI). The HEI is a density-based measure, which has been validated for individuals ages 2 years and older that calculates proximity to meeting the Dietary Guidelines for Americans 2020–2025 (U. S. Department of Health and Human Services (HHS) & U.S. Department of Agriculture (USDA), 2022). The HEI comprises two main categories (adequacy and moderation) and 13 items: total and whole fruits, greens and beans, total vegetables, whole grains, dairy, total protein foods, seafood and plant proteins, fatty acids, sodium, refined grains, saturated fats, and sugar. Scores closer to 100 indicate greater adherence to the set guidelines.

Data Analysis Plan

All analyses were conducted using the Statistical Package for the Social Science version 28 (SPSS 28). Missing data rates varied between measures (0% and 27.8%). Higher rates of missing data were due to changes in measurement procedures (i.e., the body analyzer was introduced during the second cohort of data collection) and insufficient data (i.e., <3 days of at least 10 hr of activity belt wear). According to Little's MCAR test, data were missing completely at random, $\chi^2 = 339.96$, $p > .05$. Among variables of interest, 53.4% of cases were complete. Multiple imputation procedures with 20 iterations and 5 imputations were conducted to address such missing data across analyses. All outcome measures of interest were imputed and served as predictors, along with demographic variables (e.g., ADHD diagnostic status, cohort, age, sex, maternal education, caregiver respondent, child race, and ethnicity). Analyses were rerun with and without multiple imputation, with minimal differences in the pattern of results. Thus, for a larger total sample size, we chose to report analyses with the use of multiple imputation (i.e., pooled values), but we have also included Supplementary Table 1 showing the pattern of results with only the complete data. Data were evaluated for outliers by calculating and examining z-scores for outcomes of interest. Data for one participant were removed due to their z-score being more than three standard deviations above the mean as is standard practice (Howell, 1992; Miller, 1991). Preliminary analyses evaluated associations between demographic variables and physical health variables. Simultaneous linear regression analyses examined differences between ADHD (coded as 1) and TD groups (coded as 0) in specific physical health variables. Significant interactions were probed according to

Table II. Correlations Between Variables of Interest

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1. ADHD																													
2. Cohort	−.04																												
3. Age	.11	.01																											
4. Sex	−.16*	.13	.10																										
5. Ethnicity	−.13	.08	.04	.05																									
6. Mat. Ed.	−.21*	.01	−.14*	−.08	.14*																								
7. SJ	−.16*	.04	.39**	.01	.13	−.06																							
8. PBF	.03	−.01	−.02	.13*	−.14*	−.14*	.00																						
9. BMI z-score	.08	−.08	.00	.08	−.09	−.19*	.03	.66**																					
10. Ov/O	.12	−.08	−.01	.04	−.03	−.11	.00	.56**	.64**																				
11. Steps	.08	−.06	.03	−.26**	.19**	.06	.13	−.11	−.01	.01																			
12. EE	.13*	−.03	.32**	−.09	.08	−.07	.23**	.33**	.50**	.43**	.46**																		
13. % Sed PA	−.13	−.14*	.01	.12	−.14*	.02	−.06	−.03	−.11	−.09	−.56**	−.65**																	
14. % MVPA	.14*	.09	.02	−.21**	.16*	.01	.16*	−.04	.05	.09	.68**	.72**	−.82**																
15. HEI	−.13*	.12	−.08	−.01	.01	.06	.03	.08	−.05	−.07	−.09	−.05	−.06	−.03															
16. HEI-TF	−.11	.15*	−.17*	.03	.06	.17*	.09	.00	−.02	.01	.01	−.03	−.06	−.01	.47**														
17. HEI-WF	−.08	.19*	−.04	.08	.12	.17*	.12	−.05	−.05	−.05	−.06	−.04	.02	−.05	.48**	.74**													
18. HEI-TV	−.11	.04	−.15*	.03	.07	.07	−.10	−.04	−.07	−.13*	−.07	−.10	.08	−.05	.42**	.05	.16*												
19. HEI-GB	−.09	−.04	.01	.03	−.03	−.01	.00	.00	.00	−.04	−.08	−.04	.11	−.06	.49**	.12	.16*	.40**											
20. HEI-WG	.03	.07	.01	−.01	.15*	−.01	.05	.12	.10	.03	.02	.06	−.14*	.07	.42**	.03	−.03	.15*	.03										
21. HEI-D	.08	−.05	−.07	−.04	−.04	−.16*	−.13	.03	.05	−.01	.03	−.02	.01	−.06	.02	−.06	−.09	−.07	.08	−.04									
22. HEI-PF	−.08	−.02	−.05	.07	−.05	.05	.13	.09	.10	.01	.06	.12	−.07	.12	.23**	.04	.12	.15*	.25**	.00	−.21**								
23. HEI-SPP	.01	−.06	−.10	.00	−.04	−.05	.03	.03	.11	.00	−.13*	.00	−.05	−.04	.28**	.10	.12	.12	.32**	−.03	−.06	.30**							
24. HEI-FAR	−.16*	.02	.05	−.05	.03	.12	.07	.01	−.09	−.08	.01	.04	−.05	.09	.44**	.05	.10	.14*	.08	.13*	−.57**	.23**	.05						
25. HEI-RG	−.14*	.16*	−.09	.08	−.03	.09	−.05	.04	−.03	−.01	−.05	−.01	−.14*	.04	.57**	.18**	.18**	.26*	.14*	.31**	.18**	.19**	.05	.00					
26. HEI-S	.01	.04	.02	.04	.00	.01	−.05	.00	−.10	.00	−.09	−.10	.01	−.12	.27**	.17*	.07	−.15*	−.05	−.03	.14*	−.30**	.10	−.04	.24**				
27. HEI-AS	−.06	.02	−.15*	.07	.03	.06	−.03	.07	.12	.01	.03	.07	−.03	.07	.11	.18*	.10	.21**	.20**	.15*	.03	.34**	.15*	−.02	−.08	−.32**			
28. HEI-SF	−.08	−.01	.01	−.10	.00	−.05	.01	.06	−.06	−.07	−.06	−.07	.04	−.05	.51**	.16*	.19**	.20**	.16*	.13	−.31**	.03	.07	.65**	−.05	−.02	−.15*		
29. Calories	.25**	−.20**	.07	−.24**	−.01	.07	.02	.03	.01	.14*	.06	.15*	−.12	.14*	−.10	−.07	−.09	−.12	−.10	−.06	−.08	−.15*	−.06	−.01	−.01	.08	−.20**	−.09	
30. FNPA-PA	−.15*	.14*	−.16*	−.07	.09	.05	.02	−.04	.01	.02	.05	.01	−.02	.11	.19**	.22**	.18**	.11	.14*	.03	−.09	.16*	.06	.10	.05	−.05	.19**	.10	−.04

Note. % *MVPA* = percentage of day spent in moderate-to-vigorous physical activity; % *Sed PA* = percentage of day spent in sedentary physical activity; *ADHD* = ADHD diagnostic status; *Cohort* = complete (1) vs. incomplete data collection (0); *EE* = average energy expenditure each day; *Ethnicity* = Hispanic/Latinx vs. Non-Hispanic/Latinx; *FNPA-PA* = physical activity subscore on Family Nutrition and Physical Activity scale; *HEI* = Healthy Eating Index; *HEI-AS* = HEI added sugars; *HEI-D* = HEI dairy; *HEI-FAR* = HEI fatty acids ratio; *HEI-GB* = HEI greens & beans; *HEI-PF* = HEI protein foods; *HEI-RG* = HEI refined grains; *HEI-S* = HEI sodium; *HEI-SF* = HEI saturated fats; *HEI-SPP* = HEI seafood and plant protein; *HEI-TF* = total fruits; *HEI-TV* = HEI total vegetables; *HEI-WF* = HEI whole fruits; *HEI-WG* = HEI whole grains; *Mat. Ed.* = maternal level of education; *Ov/O* = overweight/obese BMI; *PBF* = percentage body fat; *SJ* = side jumps; *Steps* = average number of steps completed each day.

* $p < .05$, ** $p < .01$.

procedures set by Aiken et al. (1991) and Hayes's macro (Hayes & Matthes, 2009). Post hoc analyses evaluated whether the differences between ADHD and TD groups in physical health variables remained significant among the Hispanic/Latinx participants. A false-discovery rate (FDR) correction (Benjamini & Hochberg, 1995) was applied within the outcome domains for regression analyses at two levels (q = .05, .10). Effect size estimates are reported via Cohen's d (small effect = .2, medium effect = .5, and large effect = >.8) and odds ratio (OR) (small effect = 1.68, medium effect = 3.47, and large effect = 6.71) (Chen et al., 2010; Cohen, 1988).

Results

Preliminary Analyses

Not surprisingly, chi-square analyses indicated that there was a higher percentage of boys within the ADHD group (62.6%) vs. the TD group (37.4%) (χ^2 (1, N = 223) = 5.585, p = .018). Additionally, several significant analysis of variance emerged as it relates to sex differences in average steps per day (F(1,221) = 15.97, p < .001), caloric intake (F(1,221) = 13.00, p <.001), MVPA (F(1,221) = 9.77, p = .002), and percentage of body fat (F(1,221) = 3.94, p = .048). See Supplementary Table 2 for means and standard deviations for boys and girls across all our outcomes. Correlational analyses (Pearson's r) indicated that age was also associated with a couple of health variables such that older children performed better on the fitness task and exerted more energy per day; see Table II for correlations between variables. Maternal education level and cohort (incomplete vs. complete data collection) were significantly correlated with several variables of interest. Therefore, age, sex, maternal education, and cohort served as covariates for subsequent analyses. EE was significantly associated with one's body weight (r = .58, p < .001), hence analyses with EE included body weight as a covariate. Additionally, greater consumption of calories was associated with several HEI components; caloric intake served as covariate in HEI analyses. See Table I for descriptive statistics.

Main Analyses

Body Composition

Logistic regression analysis revealed that children with ADHD were more likely to be classified as having an Ov/O BMI compared to TD children (OR = 2.06, 95% confidence interval = 1.08, 3.93; see Table III), indicating a small to medium effect size. In fact, 37.0% of children with ADHD were classified as having an Ov/O BMI compared to 25.0% of TD children. The diagnostic status difference in Ov/O BMI categorization did not remain statistically significant at FDR q = .10. As seen in Table IV, regression analyses indicated no significant associations between diagnostic status and BMI z-score nor body fat percentage.

Table III. Logistic Regression of Overweight/Obese BMI Status

Variables	*B*	*SE*	*OR*	95% CI LB	95% CI UB	*p*
Age	−.25	.22	0.78	0.51	1.20	.262
Sex (Ref = male)	.44	.33	1.55	0.81	2.98	.188
Cohort (Ref = complete)	−.41	.35	0.67	0.34	1.32	.246
Maternal education						
HS graduate or less	.72	.70	2.05	0.52	8.10	.309
AA graduate	.47	.50	1.60	0.60	4.24	.347
Some college	.39	.51	1.48	0.55	3.98	.441
College graduate	.12	.37	1.12	0.55	2.32	.745
Graduate degree	*Ref*	–	–	–	–	–
ADHD (*Ref* = TD)	.72	.33	2.06	1.08	3.93	.029*

Note. BMI categories were calculated based on age and sex norms from the Centers for Disease Control and Prevention (CDC, 2000) and National Center for Health Statistics. "Underweight" was categorized by a BMI percentile <5, "Healthy" or "Normal" was categorized by a BMI percentile ≥5 and <85, "Overweight" was categorized by a BMI percentile ≥85 and <95, and "Obese" was categorized by a BMI percentile ≥95.
Male = sex of participant (sex = 1); *Ref* = reference group; *Cohort* = children with complete data acquisition (Cohort = 1) versus those in initial cohort; *HS Graduate or less* = high school graduate or less; *AA Graduate* = Associate degree; *ADHD* = diagnostic status for attention-deficit/hyperactivity disorder (reference category = 0 = typically developing).
*p < .05.

Physical Activity

Regression analyses revealed no significant associations between diagnostic status and steps, percentage of the day in sedentary PA, MVPA, nor energy exerted. However, there was a significant interaction between ADHD and sex for steps. Simple slopes analysis revealed that sex moderated the association between ADHD diagnosis and steps, such that the difference in steps by diagnostic status was only present for girls (β = .47, t = 1.95, p = .05) and not for boys (β = −.13, t = −.79, p = .43). The effect size for the girls, using Cohen's d, indicated a medium effect (d = .49) As seen in Figure 1, girls with ADHD completed significantly more steps per day compared to TD girls (M = 9350.28, SE = 532.99; M = 8105.82, SE = 332.03, respectively). The diagnostic status and steps did not survive FDR correction at q = .10. As shown in Table IV, regression analyses revealed significant associations between diagnostic status and number of side jumps completed and FNPA-PA score. Those with ADHD performed worse on a fitness test with a small to medium effect size (d = −.31). Those with ADHD also had lower scores on the FNPA-PA test with a small to medium effect size (d = −.29). Significant associations between diagnostic status and side jumps survived correction at q = .05, while the association between diagnostic status and FNPA-PA did not survive correction at q = .10.

Nutrition

Regression analyses did not reveal a significant association between diagnostic status and HEI. However, analyses revealed a significant association between diagnostic status and caloric intake. Children with ADHD consumed more daily calories than TD children with a medium effect size (d = .49), and this effect remained statistically significant at FDR q =.05.

Post hoc Analyses

Finally, post hoc analyses were conducted to assess whether any link between ADHD and health outcomes was different for Hispanic/Latinx youth (coded as 1) vs non-Hispanic/Latinx youth (coded as 0). The main effects of ethnicity did not significantly change the results of the models nor did the ADHD × ethnicity interaction significantly predict any of our health outcomes. Of note, the interaction of ADHD × age also did not significantly predict any of our health outcomes. Therefore, these interaction terms were excluded in the final models depicted in our tables.

Table IV. Regression Models of Body Composition, Physical Activity, and Nutrition

Model	B	p	t
Anthropometrics			
BMI z-score			
Age	−.03	.690	−.40
Sex	.07	.342	.95
Maternal education	.17	.015*,+	−2.45
Cohort	−.08	.240	−1.18
ADHD	.08	.274	1.10
Body fat percentage			
Age	−.03	.715	−.37
Sex	.12	.105	1.63
Maternal education	−.12	.089	−1.71
Cohort	−.02	.810	−.24
ADHD	.04	.612	.51
Physical activity and fitness			
Steps			
Age	.06	.387	.87
Sex	−.69	.002**,++	−3.13
Maternal education	.07	.338	.96
Cohort	−.03	.686	−.40
ADHD	−.37	.076	−1.79
ADHD × sex	.55	.040*	2.06
Energy exerted			
Body weight	.70	<.001**,++	12.08
Age	−.01	.937	−.08
Sex	−.14	.010*,+	−2.60
Maternal education	.05	.364	.910
Cohort	.01	.837	.21
ADHD	.02	.695	.39
% day in Sed PA			
Age	.01	.836	.21
Sex	.14	.043*	2.04
Maternal education	.01	.874	.16
Cohort	−.15	.027*	−2.22
ADHD	−.10	.162	−1.40
% day in MVPA			
Age	.03	.683	.41
Sex	−.21	.003**,++	−3.03
Maternal education	.00	.983	.02
Cohort	.11	.097	1.67
ADHD	.10	.174	1.36
Side jumps			
Age	.40	<.001***,++	6.21
Sex	.02	.816	.23
Maternal education	−.06	.361	−.92
Cohort	.03	.646	.46
ADHD	−.20	.002**,+	−3.10
FNPA-PA			
Age	−.14	.047*	−2.00
Sex	−.10	.154	−1.43
Maternal education	.01	.935	.08
Cohort	.13	.050	1.97
ADHD	−.14	.047*	−2.00
Nutrition			
HEI			
Calories	−.06	.409	−.83
Age	−.07	.337	−.96
Sex	−.04	.569	−.57
Maternal education	.03	.677	.42
Cohort	.11	.105	1.63
ADHD	−.12	.104	−1.63
Calories			
Body weight	.10	.182	1.34
Age	.07	.363	.91
Sex	−.20	.003**,++	−3.02
Maternal education	.15	.024*	2.28
Cohort	−.19	.004**,++	−2.90
ADHD	.21	.002**,++	3.14

(continued)

Table IV. (continued)

Note. *Cohort* = children with complete data acquisition vs those in initial cohort; *ADHD* = diagnostic status for attention-deficit/hyperactivity disorder; *% day in MVPA* = average percentage of day spent in moderate to vigorous physical activity; *% day in Sed PA* = average percentage of day spent in sedentary physical activity; *Calories* = average calories consumed daily (kcal); *Energy exerted* = average energy exerted per day; *FNPA-PA* = average score for the physical activity items on the FNPA; *HEI* = average overall Healthy Eating Index score; *Steps* = average number of steps per day. FDR Correction: +q = .10, ++q = .05.
* $p < .05$ (uncorrected), ** $p < .01$ (uncorrected), *** $p < .001$ (uncorrected).

Discussion

The primary goal of the current study was to examine how multiple indices of physical health differ between young children with ADHD and TD children. The results suggest that young children with ADHD were more likely to have an Ov/O BMI status, be less fit, and have greater caloric intake relative to TD children. These findings are expanded below in terms of how ADHD can affect health behaviors and outcomes early in development.

It was hypothesized that young children would have not only higher BMI, but also greater percentage of body fat. Those with ADHD were more likely than TD children to be in the Ov/O BMI category which is consistent with similar research with adolescents (Cortese et al., 2016; Nigg et al., 2016), but differs from previous research with pre-adolescent children (Hanć et al., 2015; Nigg et al., 2016). Our findings suggest that differences in BMI by diagnostic status may begin around preschool age. On the other hand, we proposed that those with ADHD would have higher percentages of body fat, yet the results did not support this hypothesis. Previous research suggests that differences in body fat composition may be more prevalent later in development (Bowling et al., 2018; Martins-Silva et al., 2022).

This study revealed mixed results regarding PA differences between those with ADHD and TD young children. Objective measures of PA (i.e., accelerometer data) revealed that those with ADHD took more steps per day, and the significant difference in steps by sex was only present among TD participants. Although those with ADHD took more steps, those children were less fit. Our finding of poor fitness in those with ADHD is consistent with past work highlighting motor coordination difficulties among young children with ADHD (Harvey & Reid, 2003; Kaiser et al., 2015). Parents also reported less family opportunities for PA, which may give those with ADHD fewer opportunities to develop motor coordination and fitness levels. Lower levels of fitness at a young age may put those with ADHD at risk of engaging in less PA later and developing lifestyle-related health issues later in life (García-Hermoso et al., 2019).

It was hypothesized that children with ADHD would have a greater caloric intake and worse nutritional quality scores compared to TD children. In this study, children with ADHD

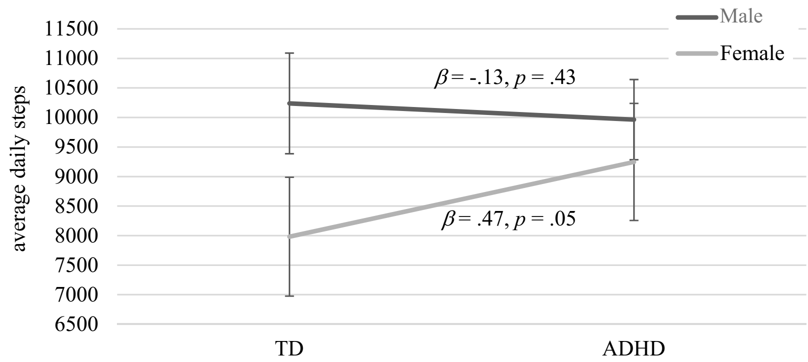

Figure 1. The simple slopes of the interaction of ADHD and sex predicting steps. ADHD = attention-deficit/hyperactivity disorder; TD = typically developing.

had greater caloric intake but did not differ in meeting nutritional guidelines. These findings with nutritional measures provide initial evidence for disparities in caloric intake between those with and without ADHD. While this study did not observe nutritional quality differences, greater impulsivity and poor response inhibition may also explain why children with ADHD consume more calories (Davis et al., 2006; Nigg et al., 2016). There may also be shared neurobiological underpinnings (i.e., reward sensitivity) that may put those with ADHD at greater risk for overeating and, as a result, obesity (Bazar et al., 2006; Cortese et al., 2008).

This study is not without limitations. Because this study analyzed data at a single timepoint, this study is unable to establish causality between ADHD and physical health metrics and outcomes. Longitudinal data analyses can better evaluate how ADHD diagnosis or severity reflects changes in physical health habits and outcomes over time. Given that our ADHD sample was comprised mostly of the combined presentation (92.13%), we were not able to investigate further differences in the physical health measures by ADHD diagnostic presentation. This is an important area for future work because two proposed theories for the differences in body composition between those with and without ADHD are related to the two key symptoms categories: impulsivity and inattention (Cortese & Peñalver, 2010; Cortese & Vincenzi, 2012). Another limitation of this study was that our fitness assessment was brief and may not provide a comprehensive measure of fitness. Other studies evaluating fitness incorporate a battery of tests to measure multiple metrics (Bös et al., 2004; Ortega et al., 2015). Our measure of nutrition relied on subjective parental report of their child's food consumption. Future work should use more objective measures of nutritional quality such as reflectance spectroscopy, a way to measure carotenoids in the skin related to fruit and vegetable intake (Meinke et al., 2016). Finally, this study experienced missing data due to delayed equipment acquirement and data collection. Furthermore, some significant findings, which were in the small to medium range of effect sizes, did not survive FDR correction at the $q = .05$ level. It is essential that studies evaluate the robustness of the associations between ADHD and physical health with larger and complete sample sizes as well as diverse populations.

As it relates to the generalizability of our findings, it is noteworthy that this sample consisted of predominantly Hispanic/Latinx youth with college-educated mothers, and within the ADHD sample, those youth were medication naive and required to attend an 8-week summer treatment program. Subsequent research ought to replicate this study's analyses with different participant populations as it is well known that race, ethnicity, socioeconomic status, and medication status can have significant effects on nutritional practices, PA, and, ultimately, obesity (Kumanyika, 2008; McLaren, 2007; Wright & Aronne, 2012). Finally, this study provides an individual-level, PA and nutrition view of the incidence of pediatric obesity. Additional factors such as sleep, neighborhood environment, socioeconomic status, and parental feeding practices can influence youth's body composition. Future studies should expand on this study by evaluating how other contexts within the EST interact with individual-level factors to contribute to pediatric obesity among those with ADHD.

Beyond individual-level factors of pediatric obesity, there is significant work documenting how an "obesogenic environment" influences children's health behaviors (Swinburn et al., 1999). Thus, the next steps for identifying poor health behaviors in young children with ADHD include examining the home environment and family factors that promote certain health behaviors, especially given that Hispanic/Latinx families may be more collectivistic and family oriented than non-Hispanic/Latinx families within the United States (Marin & Triandis, 1985; Smith-Morris et al., 2013). At an individual level, understanding young children's self-regulation skills with respect to physical health behaviors would also be important given that individuals' efforts to control their behavioral responses and inner states are lacking in those with ADHD as well as those who engage in binging behaviors (Graziano et al., 2013; Hughes et al., 2015).

Following the identification of health characteristic differences in children with and without ADHD as well as their mechanisms, interventions can then be explored in their effects on obesity-related behaviors. Given that the recommended interventions for early childhood ADHD are behaviorally focused, this study's findings suggest that there are relevant health-based behaviors that ought to be targeted in early interventions as well. Several parenting programs (e.g., Triple P, Incredible Years) have indirect benefits on physical health through parenting factors like increasing consistency and parental monitoring (Gerards et al., 2012; Gubbels et al., 2018; Klesges et al., 1991; Morrison et al., 2014; Park & Walton-Moss, 2012). Interventions focused on parent and reward sensitivity training should be explored further in how they relate to the future development of obesity.

In summary, the current study provided comprehensive analyses of key physical health metrics and how they differ in young children with and without ADHD in a predominantly Hispanic/Latinx sample. Strengths include a variety of metrics to study physical health beyond BMI and evaluations of sex and diagnostic status interactions. Our results contribute to the current literature as well as provide evidence that those with ADHD may be at greater risk for being less fit, consuming more calories, and ultimately having greater risk for having an Ov/O BMI compared to TD children. Given the age and ethnicity of our sample, it appears that the relationship between ADHD and poor physical health may be prevalent in Hispanic/Latinx populations and may be occurring earlier than previously identified. As the obesity epidemic continues, identifying vulnerable populations is essential for prevention. Future work should identify how ADHD contributes to poor physical health behaviors as well as how parenting interventions can promote positive physical health behaviors such as PA and nutrition.

Supplementary Data

Supplementary data can be found at: https://academic.oup.com/jpepsy.

Author Contributions

Madeline Marie Curzon (Conceptualization [lead], Data curation [lead], Formal analysis [lead], Investigation [lead], Project administration [supporting], Visualization [lead], Writing—original draft [lead], Writing—review & editing [equal]), Anthony Dick (Conceptualization [equal], Funding acquisition [equal], Investigation [equal], Methodology [equal], Project administration [equal], Resources [equal]), Catherine Coccia (Data curation [supporting], Funding acquisition [equal], Investigation [equal], Methodology [equal], Project administration [equal], Resources [supporting], Writing—review & editing [supporting]), and Paulo Graziano (Conceptualization [equal], Formal analysis [equal], Funding acquisition [lead], Investigation [lead], Methodology [equal], Resources [equal], Supervision [lead], Writing—original draft [supporting], Writing—review & editing [supporting])

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Conflicts of interest

None declared.

Data Availability

Data are available upon request.

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