Research in Autism Spectrum Disorders 70 (2020) 101490

Contents lists available at ScienceDirect

Research in Autism Spectrum Disorders

journal homepage: www.elsevier.com/locate/rasd

Brief Report

# Physical activity rates in children and adolescents with autism spectrum disorder compared to the general population

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ARTICLE INFO

*Keywords:*
Autism
Physical exercise
Pediatrics

ABSTRACT

Physical activity may improve symptoms and skill deficits associated with autism spectrum disorder (ASD). The objective of this study was to compare the reported frequency of physical activity and covariates in a large sample of children with ASD with children of similar age from the general population. The sample with ASD was derived from the Autism Treatment Network Registry Call Back Assessment (n = 611), and the general population data were derived from the National Survey of Children's Health (NSCH) (n = 71,811). In addition, demographic, child, and family (parent) factors were examined in relation to frequency of recent physical activity in children with ASD. Among males in the 6 – 11 year-old age group, those with ASD participated in physical activity less often ($p < 0.001$) than those in the NSCH general population. Specifically, 33 % of boys 6 – 11 years old in the NSCH group vs. only 17 % in the RCBA group 6 – 11 years old engaged in some physical activity every day, while 4 % of boys in the NSCH group vs. 18 % in the RCBA group engaged in no physical activity whatsoever. A similar effect was seen across other age groups and in females but was not statistically significant. The demographic, child, and family characteristics associated with physical activity in children and adolescents with ASD included ethnicity in females, DSM-IV ASD diagnosis, IQ, and PAM-13 total score in females. Parents and caregivers are encouraged to find suitable physical activity programs for children with ASD. This may be especially important for 6 – 11 year-old boys with ASD who engage in significantly less physical activity than their peers in the general population.

## 1. Introduction

Physical activity has been shown to improve many areas of concern for children with Autism Spectrum Disorder (ASD) (Sam, Chow, & Tong, 2015; Sowa & Meulenbroek, 2012). A recent meta-analysis found that the positive effects of physical activity in youth

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https://doi.org/10.1016/j.rasd.2019.101490
Received 5 June 2019; Received in revised form 21 November 2019; Accepted 24 November 2019
1750-9467/ 

with ASD were most marked for fine motor coordination, locomotor skills, muscular strength/endurance, and social functioning (Healy, Nacario, Braithwaite, & Hopper, 2018). In addition, research has shown that physical activity in children with ASD is associated with improved academic performance (Oriel, George, Peckus, & Semon, 2011), increased communication, cooperation, and self-control skills (Chan, Sze, Siu, Lau, & Cheung, 2013; Zhao & Chen, 2018), decreased stereotypy (Bahrami, Movahedi, Marandi, & Abedi, 2012), and improved parent-reported quality of life (Toscano, Carvalho, & Ferrerira, 2018).

As in the general pediatric population in the United States, many youth with ASD do not engage in sufficient physical activity (Healy, Haegele, Grenier, & Garcia, 2017; Neumeyer et al., 2018). A recent report by the National Physical Activity Plan Alliance revealed that only 24 % of 6–17 year-olds in the United States participated in the recommended 60 min of physical activity per day (National Physical Activity Plan Alliance (NPAPA, 2018). Only 14 % of youth in this age group diagnosed with ASD met this recommendation as children and adolescents with ASD engage in less physical activity than their peers in both structured programing, such as a physical education class, and in their free time (Pan, Tsai, Chu, & Hsieh, 2011, 2016; Stanish et al., 2017). This discrepancy may stem in part from underlying differences in motivation for physical activity and impairments associated with core-ASD related symptoms that challenge participation, particularly in group settings (Pan et al., 2011). Barriers to successful inclusion of individuals with ASD in recreational physical activity also include limited resources and staff training (Gregor et al., 2018; Obrusnikova & Miccinello, 2012; Shields, Synnot, & Barr, 2012). Additionally, parents may lack information regarding accessible physical activity programs and they may find it difficult to facilitate physical activity experiences in the context of demands related to other needed intervention services (Gregor et al., 2018).

Reduced levels of physical activity in youth with ASD may lead to further health problems including obesity and lower bone density (Broder-Fingert, Brazauskas, Lindgren, Iannuzzi, & Van Cleave, 2014; Neumeyer, Gates, Ferrone, Lee, & Misra, 2013). Compared to neurotypical peers, children with ASD have significantly higher odds of being overweight and obese (Broder-Fingert et al., 2014). Within the ASD population, older children (12–15 years) and those who are uninsured or with public insurance alone have higher odds of being overweight and obese compared to children ages 6–11 and those with private insurance (Broder-Fingert et al., 2014). Lower levels of physical activity may further contribute to this risk. Reduced physical activity rates among children with ASD may protect against fractures during the childhood years (Furlano, Bloechliger, Jick, & Meier, 2014), despite the lower bone density reported in this population (Neumeyer et al., 2013, 2015). However, low bone accrual rates during the childhood and adolescent years could lead to reduced peak bone mass and increased fracture risk in adult life, as has been reported in adults with ASD (Neumeyer et al., 2015).

In this paper, we describe physical activity rates, as well as their determinants, in a large cohort of children diagnosed with ASD in the Autism Treatment Network (ATN) database compared to children in the National Survey of Children's Health (NSCH). The study has two primary aims. Aim 1 compares the reported frequency of recent physical activity between children with ASD in the ATN sample and national data derived from the NSCH (Child and Adolescent Health Measurement Initiative, 2016–17). Aim 2 examines the association of demographic (i.e., age, gender, ethnicity, race, insurance status, family income and caregiver education level), child (i.e., DSM-IV diagnosis, ASD core symptom severity, degree of adaptive and problem behaviors, sensory issues, developmental functioning and health), and family factors (i.e., caregiver strain and parent engagement) to the reported frequency of recent physical activity in children with ASD. We expected lower socioeconomic status, as well as specific child characteristics (elevated child ASD-related symptoms, lower current level of adaptive behavior, the presence of intellectual disability and comorbid behavior problems) to be associated with a lower frequency of recent physical activity in children with ASD. Conversely, we expected greater parent activation and lower caregiver strain to be associated with a higher frequency of recent physical activity. To our knowledge, this is the first paper that 1) examines the frequency of physical activity and associated demographic, child, and family factors by gender and age, 2) uses a large sample of children and adolescents with ASD from a well-established treatment network (i.e., the ATN), and 3) compares the frequency of physical activity by gender and age to a large and representative national data set (i.e., National Survey of Children's Health).

## 2. Methods

### 2.1. Participants

The sample of children with ASD consists of a cohort enrolled in the ATN's Registry Call Back Assessment (RCBA) who are under the age of 18 years, who completed a second RCBA visit, and whose parents completed the physical activity questions of the parent questionnaire. The RCBA was started in 2015 to collect additional long-term follow-up data from registry participants. RCBA participants were recruited from the 12 sites active in the ATN during this time period. Each site received randomly generated lists of 65 registry participants from which they enrolled 50 participants (additional lists were provided when enrollment goals were not met). Data from when children entered the ATN registry are considered baseline data whereas data collected at the RCBA visit represents follow-up data. Participants who enrolled into the RCBA did not differ substantially from participants who were identified but declined participation based on comparisons of demographic data (see Table 1 for RCBA demographic characteristics). The general population sample (n = 71,811) was derived from the NSCH reports from 2016 and 2017 (Child and Adolescent Health Measurement Initiative, 2016–17). The survey was sent to randomly selected addresses from non-institutionalized households across the United States. In each household one of the children was selected at random with differential weighting to over sample children with special needs and children 0-to 5 years-old. As reports of special needs were not verified by an official diagnosis, our sample does not exclude those with caregiver reported ASD and is therefore representative of the general pediatric population inclusive of children with disabilities.

**Table 1**
Demographics.

| Variable | Level | | Female | Male | Overall |
|---|---|---|---|---|---|
| Age at RCBA Visit | | n, missing | 71, 0 | 304, 0 | 375, 0 |
| | | Mean (SD) | 10.20 (3.33) | 9.64 (3.05) | 9.75 (3.11) |
| | | 95 % CI | 9.42, 10.99 | 9.29, 9.98 | 9.43, 10.06 |
| | | min, max | 5.06, 17.47 | 4.55, 17.94 | 4.55, 17.94 |
| | | Median | 9.67 | 8.95 | 9.08 |
| | | IQR | 7.65, 12.99 | 7.13, 11.69 | 7.23, 11.74 |
| Age at RCBA Visit (Groups) | Summary: | n, missing | 71, 0 | 304, 0 | 375, 0 |
| | 1. 0–5 Years | n (%) | 4 (5.6 %) | 19 (6.3 %) | 23 (6.1 %) |
| | 2. 6–11 Years | n (%) | 47 (66.2 %) | 220 (72.4 %) | 267 (71.2 %) |
| | 3. 12–17 Years | n (%) | 20 (28.2 %) | 65 (21.4 %) | 85 (22.7 %) |
| Gender | Summary: | n, missing | 71, 0 | 304, 0 | 375, 0 |
| | Female | n (%) | 71 (100 %) | 0 (0.0 %) | 71 (18.9 %) |
| | Male | n (%) | 0 (0.0 %) | 304 (100 %) | 304 (81.1 %) |
| Ethnicity | Summary: | n, missing | 68, 3 | 292, 12 | 360, 15 |
| | Hispanic | n (%) | 6 (8.8 %) | 19 (6.5 %) | 25 (6.9 %) |
| | Non-Hisp | n (%) | 62 (91.2 %) | 273 (93.5 %) | 335 (93.1 %) |
| DSM-IV ASD Diagnosis | Summary: | n, missing | 71, 0 | 304, 0 | 375, 0 |
| | Asperger's | n (%) | 9 (12.7 %) | 24 (7.9 %) | 33 (8.8 %) |
| | Autism | n (%) | 50 (70.4 %) | 219 (72.0 %) | 269 (71.7 %) |
| | PDD/NOS | n (%) | 12 (16.9 %) | 61 (20.1 %) | 73 (19.5 %) |
| Race | Summary: | n, missing | 71, 0 | 294, 10 | 365, 10 |
| | Asian | n (%) | 4 (5.6 %) | 13 (4.4 %) | 17 (4.7 %) |
| | Black or African Am./Black Canadian | n (%) | 3 (4.2 %) | 16 (5.4 %) | 19 (5.2 %) |
| | Caucasian/White | n (%) | 60 (84.5 %) | 240 (81.6 %) | 300 (82.2 %) |
| | Other/Multiracial | n (%) | 4 (5.6 %) | 25 (8.5 %) | 29 (7.9 %) |
| Highest Education Level of known CGs: HS Split | Summary: | n, missing | 69, 2 | 294, 10 | 363, 12 |
| | HS or less | n (%) | 6 (8.7 %) | 33 (11.2 %) | 39 (10.7 %) |
| | More than HS | n (%) | 63 (91.3 %) | 261 (88.8 %) | 324 (89.3 %) |
| Insurance: Has Public Insurance | Summary: | n, missing | 71, 0 | 303, 1 | 374, 1 |
| | No | n (%) | 33 (46.5 %) | 166 (54.8 %) | 199 (53.2 %) |
| | Yes | n (%) | 38 (53.5 %) | 137 (45.2 %) | 175 (46.8 %) |
| Insurance: Has Private Insurance | Summary: | n, missing | 71, 0 | 303, 1 | 374, 1 |
| | No | n (%) | 28 (39.4 %) | 102 (33.7 %) | 130 (34.8 %) |
| | Yes | n (%) | 43 (60.6 %) | 201 (66.3 %) | 244 (65.2 %) |
| Insurance: Has no insurance | Summary: | n, missing | 71, 0 | 303, 1 | 374, 1 |
| | No | n (%) | 67 (94.4 %) | 294 (97.0 %) | 361 (96.5 %) |
| | Yes | n (%) | 4 (5.6 %) | 9 (3.0 %) | 13 (3.5 %) |
| Income | Summary: | n, missing | 60, 11 | 243, 61 | 303, 72 |
| | $50k+ | n (%) | 23 (38.3 %) | 95 (39.1 %) | 118 (38.9 %) |
| | < $50k | n (%) | 37 (61.7 %) | 148 (60.9 %) | 185 (61.1 %) |
| Weight (kg) (RCBA) | | n, missing | 59, 12 | 218, 86 | 277, 98 |
| | | Mean (SD) | 45.39 (17.79) | 44.79 (22.00) | 44.91 (21.15) |
| | | 95 % CI | 40.75, 50.02 | 41.85, 47.72 | 42.41, 47.42 |
| | | min, max | 20.90, 97.93 | 14.30, 120.20 | 14.30, 120.20 |
| | | Median | 40.80 | 36.90 | 38.80 |
| | | IQR | 31.75, 54.00 | 28.12, 54.43 | 29.03, 54.40 |
| Height (m) (RCBA) | | n, missing | 58, 13 | 216, 88 | 274, 101 |
| | | Mean (SD) | 1.45 (0.14) | 1.45 (0.18) | 1.45 (0.17) |
| | | 95 % CI | 1.42, 1.49 | 1.43, 1.48 | 1.43, 1.47 |
| | | min, max | 1.19, 1.69 | 1.00, 1.87 | 1.00, 1.87 |
| | | Median | 1.45 | 1.41 | 1.42 |
| | | IQR | 1.32, 1.58 | 1.32, 1.59 | 1.32, 1.59 |
| BMI (RCBA) | | n, missing | 58, 13 | 215, 89 | 273, 102 |
| | | Mean (SD) | 20.97 (5.25) | 20.03 (5.57) | 20.23 (5.51) |
| | | 95 % CI | 19.59, 22.35 | 19.28, 20.78 | 19.57, 20.89 |

(*continued on next page*)

**Table 1** (*continued*)

| Variable | Level | | Female | Male | Overall |
|---|---|---|---|---|---|
| | | min, max | 13.34, 34.32 | 12.54, 39.79 | 12.54, 39.79 |
| | | Median | 19.83 | 18.36 | 18.71 |
| | | IQR | 17.59, 23.69 | 15.71, 22.44 | 15.93, 22.78 |
| BMI Percentile (RCBA) | | n, missing | 58, 13 | 215, 89 | 273, 102 |
| | | Mean (SD) | 0.71 (0.28) | 0.66 (0.33) | 0.67 (0.32) |
| | | 95 % CI | 0.64, 0.79 | 0.62, 0.71 | 0.63, 0.71 |
| | | min, max | 0.02, 1.00 | 0.00, 1.00 | 0.00, 1.00 |
| | | Median | 0.82 | 0.77 | 0.78 |
| | | IQR | 0.52, 0.96 | 0.40, 0.96 | 0.44, 0.96 |
| Intellectual Disability | Summary: | n, missing | 68, 3 | 280, 24 | 348, 27 |
| | No | n (%) | 37 (54.4 %) | 131 (46.8 %) | 168 (48.3 %) |
| | Yes | n (%) | 31 (45.6 %) | 149 (53.2 %) | 180 (51.7 %) |
| IQ | | n, missing | 61, 10 | 247, 57 | 308, 67 |
| | | Mean (SD) | 79.72 (25.22) | 75.06 (22.23) | 75.99 (22.88) |
| | | 95 % CI | 73.26, 86.18 | 72.28, 77.85 | 73.42, 78.55 |
| | | min, max | 44.00, 130.00 | 40.00, 132.00 | 40.00, 132.00 |
| | | Median | 82.00 | 73.00 | 73.50 |
| | | IQR | 51.00, 98.00 | 53.00, 93.00 | 53.00, 96.00 |

Variables were collected at registry baseline unless otherwise noted.

The study was approved by each site's Institutional Review Board. Prior to participation, written consent was obtained from participants' parents and caregivers at each site.

### 2.2. Procedure

Recent physical activity was captured in the RCBA with a question chosen to match the physical activity question in the NSCH. Parents were asked "DURING THE PAST WEEK, on how many days did your child exercise, play a sport, or participate in physical activity for at least 60 min?" and could respond as "0 days", "1–3 days", "4–6" days or "Everyday". Responses were summarized for the full population and separately for age groups of 6 − 11 years and 12–17 years as counts/percent. Physical activity data from the RCBA were compared to physical activity data from the NSCH within age groups of 6 − 11 years and 12–17 years. We imputed an effective sample size from the NSCH weighted estimate to match the confidence intervals provided by NSCH. A Fisher's Exact test was used to compare the distribution of physical activity in RCBA to NSCH in each age group.

Three types of factors were analyzed as potential correlates of physical activity in the RCBA children including demographics, child factors, and family factors. Variables were taken from the registry baseline visits and from RCBA visits where available. Demographics included age, gender, ethnicity, race, insurance status, family income and caregiver education level. Clinically relevant child factors included variables directly related to a child's ASD such as DSM-IV diagnosis type, ASD core symptom severity measured by the ADOS™-2, and ASD symptom severity measured by the AIM Provisional Total Impact Score and AIM Provisional Total Frequency Score (Kanne et al., 2014; Lord & Rutter, 2012), degree of adaptive and problem behaviors at registry baseline and call-back assessment measured by the Vineland Composite score and Child Behavior Checklist: Total, Externalizing, and Internalizing scores (Achenbach, 2009, Sparrow, Cicchetti, & Saulnier, 2016), and sensory issues measured by the Short Sensory Profile: Tactile, Auditory, Visual, Taste, Movement, Under-responsiveness, Weak, and Total scores (Dunn, 1999). They also included characteristics related to the child's developmental functioning and health independent of their ASD diagnosis including intellectual disability status, IQ (Wechsler, 2003), height, weight, BMI, and BMI percentile. Family factors included the reported level of caregiving strain associated with having a child with ASD, as well as level of parent engagement in managing the child's health measured by the CGSQ Global Score and the PAM-13 Activation Level and PAM-13 Total Score respectively (Brannan, Heflinger, & Bickman, 1997; Ruble, Murray, McGrew, Brevoort, & Wong, 2018).

Associations of physical activity with demographic, child and family factors were assessed using Spearman's correlation for continuous factors and using a Cochran-Armitage trend test for categorical factors. These associations were assessed in the overall group, and also separately for males and females.

## 3. Results

Out of the 407 participants who participated in the RCBA follow up visit, parents of 375 participants under 18 years of age provided complete data on recent physical activity. The sample was predominately male (81 %, n = 304), non-Hispanic (93 %, n = 335), Caucasian/white (82 %, n = 300), and between the ages of 6–11 (71 %, n = 267). The NSCH sample of 71,811 was weighted to be representative of the general population, and was evenly split by sex (51 % male and 49 % female), mostly non-Hispanic (75 %), and evenly split across age groups (32 % between 0–5 years, 34 % between 6 − 11 years, and 34 % between 12–17 years).

The results showed that the overall distribution of physical activity rates was significantly different between the NSCH and RCBA

**Table 2**
NSCH and RCBA Rates and Percentages of Physical Activity (60 min or more) in 6–11 and 12–17 Year Old Males and Females.

| | | | Physical Activity in Past Week | | | | |
|---|---|---|---|---|---|---|---|
| Gender | Age Group (yrs) | Data Source | 0 days | 1-3 days | 4-6 days | Everyday | p |
| Female | 6–11 | NSCH | 114 (6 %) | 688 (35 %) | 724 (36 %) | 462 (23 %) | 0.090 |
| | | RCBA | 6 (13 %) | 18 (38 %) | 11 (23 %) | 12 (26 %) | |
| | 12–17 | NSCH | 468 (18 %) | 1041 (41 %) | 677 (27 %) | 358 (14 %) | 0.62 |
| | | RCBA | 2 (10 %) | 11 (55 %) | 4 (20 %) | 3 (15 %) | |
| Male | 6–11 | NSCH | 82 (4 %) | 685 (33 %) | 631 (30 %) | 681 (33 %) | < 0.001 |
| | | RCBA | 39 (18 %) | 108 (49 %) | 35 (16 %) | 38 (17 %) | |
| | 12–17 | NSCH | 360 (13 %) | 987 (35 %) | 935 (33 %) | 529 (19 %) | 0.14 |
| | | RCBA | 13 (20 %) | 26 (40 %) | 19 (29 %) | 7 (11 %) | |

sample for 6 − 11 year-old males ($p < 0.001$) (see Table 2). Compared to the NSCH sample in the male 6 − 11 year-old group, same-aged males in the RCBA sample tended to engage in physical activity less often. In this age range, 33 % of boys in the NSCH group vs. only 17 % in the RCBA group engaged in some physical activity every day, while 4 % of boys in the NSCH group vs. 18 % in the RCBA group engaged in no physical activity whatsoever. Older males and younger females in the RCBA sample also tended to engage in physical activity less often compared to the general population for their age and sex; however, these trends were not statistically significant. When comparing females 12–17 years-old in the RCBA and NSCH groups, the pattern is less clear (see Table 2).

In the overall sample, the only significant difference in physical activity rates related to demographic variables was noted for ethnicity (Hispanic/non-Hispanic) in females ($p = 0.04$), possibly a spurious finding due to the small sample size (only 6 (9 %) of the 68 were Hispanic). The only significant differences related to child characteristics (see Table 3) were for (i) baseline IQ in males, with

**Table 3**
Factors Associated with Physical Activity in the RCBA Cohort.

| Factor | Physical Activity (4 levels) | | |
|---|---|---|---|
| | Overall | Females | Males |
| Demographics | | | |
| Age (RCBA) | 0.050 | 0.40 | 0.055 |
| Sex | 0.095 | | |
| Race | 0.21 | 0.50 | 0.056 |
| Ethnicity | 0.29 | **0.040** | > 0.99 |
| Highest Education Level of known CGs: HS Split | 0.11 | 0.79 | 0.093 |
| Income | 0.50 | 0.35 | 0.23 |
| Insurance: Has Private Insurance | 0.15 | 0.48 | 0.24 |
| Insurance: Has Public Insurance | 0.37 | 0.61 | 0.52 |
| Insurance: Has no insurance | 0.50 | 0.87 | 0.41 |
| Child Characteristics | | | |
| ADOS | 0.56 | 0.34 | 0.28 |
| Adaptive Behavior Composite Standard Score | 0.85 | > 0.99 | 0.81 |
| BMI Percentile (RCBA) | 0.81 | 0.14 | 0.67 |
| CBCL Externalizing T | 0.66 | 0.75 | 0.55 |
| CBCL Internalizing T | 0.83 | 0.70 | 0.72 |
| CBCL Total Problems T | 0.35 | 0.90 | 0.30 |
| DSM-IV ASD Diagnosis | **0.017** | 0.25 | **0.038** |
| IQ | **0.001** | 0.46 | < **0.001** |
| Intellectual Disability | 0.24 | 0.74 | 0.20 |
| AIM Provisional Total Frequency Score (RCBA) | 0.97 | 0.18 | 0.51 |
| AIM Provisional Total Impact Score (RCBA) | 0.37 | 0.17 | 0.85 |
| SSP Total Score (RCBA) | 0.46 | 0.29 | 0.25 |
| SSP Auditory Score (RCBA) | 0.82 | 0.27 | 0.52 |
| SSP Tactile Score (RCBA) | 0.17 | 0.59 | 0.078 |
| SSP Under-responsiveness Score (RCBA) | **0.033** | **0.001** | 0.30 |
| SSP Visual Score (RCBA) | 0.82 | 0.55 | 0.71 |
| SSP Weak Score (RCBA) | **0.002** | 0.093 | **0.007** |
| Family Characteristics | | | |
| CGSQ Global Score (RCBA) | 0.44 | 0.38 | 0.75 |
| PAM-13 Activation Level (RCBA) | 0.27 | 0.14 | 0.58 |
| PAM-13 Total Score (RCBA) | 0.32 | **0.014** | 0.88 |

Factors were collected at registry baseline unless otherwise noted p values below 0.05 are in bold.

higher IQ scores being associated with less physical activity at follow up ($p < 0.001$), (ii) DSM-IV ASD diagnosis, with males diagnosed with Asperger's syndrome getting less physical activity than males diagnosed with Autism and PDD/NOS ($p = 0.04$), and (iii) sensory under-responsiveness (females $p = 0.001$) and weakness (males $p = 0.007$) in the short sensory profile. The only family level difference that reached significance for any group was the PAM-13 Total score for females. Parents of girls who engaged in physical activity more often reported higher levels of parent activation or engagement compared to parents of girls who engaged in physical activity less frequently ($p = 0.014$).

## 4. Discussion

The findings suggest that 6 − 11 year-old males with ASD in the RCBA sample engaged in physical activity less frequently compared to the NSCH sample, corroborating previous research using actigraphy in a smaller sample (Bandini et al., 2012). Previous results focusing on 13-year-old children (Healy et al., 2017) and adolescents with ASD (Pan et al., 2016; Stanish et al., 2017) were not corroborated by our findings. Although older males and females with ASD also showed less frequent physical activity compared to the NSCH sample, the findings were not statistically significant. Females aged 6 − 11 years in the RCBA group did not show a consistent pattern, with a higher proportion having either no days of physical activity or daily physical activity compared to the NSCH sample.

In general, the 12–17 year-old males and females in both the RCBA and the NSCH samples engaged in physical activity less often than the 6 − 11 year-olds. For example, thirteen percent of the 12–17 year-old males in the NSCH sample reported engaging in physical activity 0 days per week compared to only 4 % of the 6 − 11 year-old males. In the RCBA group, 20 % of the 12–17 group and 18 % of the 6–11 group reported engaging in physical activity 0 days per week. These findings corroborate previous studies showing that age is inversely associated with physical activity in children with ASD (Jones et al., 2017) as well as in the general pediatric population (Cooper et al., 2015; Farooq et al., 2018). While these low physical activity rates in all groups of males from both samples are worrisome (US Department of Health and Human Services (HHS, 2018), it is particularly striking that males with ASD engage in such low levels of physical activity from a young age.

Previous research suggested that demographic, child, and family (parent) factors may be related to reported rates of physical activity in the general population (Rebold, Lepp, Kobak, McDaniel, & Barkley, 2016; Gunter, Jackson, Tomayko, & John, 2017). In this study, only a few demographic, child, and family characteristics were associated with physical activity in children and adolescents with ASD, which included ethnicity in females, DSM-IV ASD diagnosis, IQ, and PAM-13 total score in females. Future work would benefit from examining mechanisms that might account for observed associations between IQ and physical activity in the current study. Attention to the potential role of social awareness, peer-related stressors, and restricted interests may be particularly important in this effort. Furthermore, it is possible that parents of children with high IQs prioritize scheduling academic or other services over opportunities for physical activity during the parent's limited free time (Gregor et al., 2018). However, the significant association of IQ with engagement in physical activity at follow up in males and overall, as well as of ethnicity and parent engagement with follow up physical activity rates in females should be interpreted with caution as a large number of covariates were analyzed and some these relationships might be significant due to chance alone.

Limitations exist with regard to sample characteristics in this study, and it will be important to replicate and extend these findings in samples with greater racial, ethnic, and socioeconomic diversity. Older children were underrepresented in the RCBA data leading to low power for comparisons in the older age group. Our participating families may represent a relatively select group of highly-engaged parents, and it is possible that this may have limited our ability to detect expected associations between family-level factors and rates of reported physical activity. In addition, the current study utilized parent questionnaires, which have been shown to overestimate physical activity rates compared to accelerometry measurement (Bandini et al., 2012). Finally, the study did not assess the type and context of physical activity, which could differ between age groups. For instance, younger children may receive most of their physical activity in school and this could be an interesting finding to explore further in future studies.

## 5. Conclusion

Given the positive effects of physical activity on children with ASD, parents and caregivers are encouraged to find suitable physical activity programs and opportunities for them. This is especially important in younger males with ASD, as they were found to engage in significantly less physical activity than the general population, a habit that may impact future health behavior and could lead to higher rates of obesity and other health problems. Future studies should include more ethnically and socioeconomically diverse samples, as well as objective measures of physical activity, to better understand predictors of physical activity rates in this population.

## Funding

This Network activity was supported by Autism Speaks and cooperative agreementUA3 MC11054 through the U.S. Department of Health and Human Services, Health Resources and Services Administration, Maternal and Child Health Research Program to the Massachusetts General Hospital. This work was conducted through the Autism Speaks Autism Treatment Network. This information or content and conclusions are those of the author and should not be construed as the official position or policy of, nor should any endorsements be inferred by HRSA, HHS, the U.S. Government, or Autism Speaks. This work was conducted through the Autism Speaks Autism Treatment Network serving as the Autism Intervention Research Network on Physical Health.

## Declaration of Competing Interest

Jean-G. Gehricke declares that he has no conflict of interest; James Chan declares that he has no conflict of interest; Justin Farmer declares that he has no conflict of interest; Rachel M. Fenning declares that she has no conflict of interest; Robin Steinberg-Epstein declares that she has no conflict of interest; Madhusmita Misra declares that she has no conflict of interest; Robert A. Parker declares that he has no conflict of interest; Ann M. Neumeyer declares that she has no conflict of interest.

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