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ORIGINAL PAPER

Physical Activity Levels, Frequency, and Type Among Adolescents with and Without Autism Spectrum Disorder

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Abstract We compared time spent in moderate and vigorous physical activity (MVPA), type, and frequency of participation in physical activities between adolescents with ASD (n = 35) and typically developing (TD) adolescents (n = 60). Accelerometers measured MVPA and participants were interviewed about engagement in physical activities. Adolescents with ASD spent less time in MVPA compared to TD adolescents (29 min/day vs. 50 min/day, $p < 0.001$) and fewer met the Physical Activity Guidelines for Americans (14 vs. 29%, $p > 0.05$). Among adolescents <16 years old, those with ASD participated in fewer activities than TD adolescents (5.3 vs. 7.1 activities, $p < 0.03$). Walking/hiking and active video gaming were among the top activities for both groups. Findings support the need for interventions that meet the needs of youth with ASD.

Keywords Accelerometry · Physical activity · Youth · Health · Exercise · Autism spectrum disorder

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Introduction

The health benefits associated with participation in physical activity for children and adolescents are highlighted in the U.S. Department of Health and Human Services (USDHHS) Healthy People 2020 initiative and include improved cardiorespiratory and muscular fitness, improved bone health, decreased body fat, and reduced depressive symptomatology (USDHHS 2008a). The Physical Activity Guidelines for Americans recommend that children and adolescents ages 6–17 years engage in a minimum of 60 min of moderate-to-vigorous intensity physical activity (MVPA) each day to achieve these health benefits (USDHHS 2008b). Despite strong evidence that supports the importance of physical activity for health and quality of life, data obtained from a nationally representative sample indicate that only 42% of children ages 6–11 years and 8% of adolescents ages 12–19 years met the Guidelines in 2003–2004 (Troiano et al. 2008). More recent data further support that only 25% of U.S. youth engage in 60 min/day of MVPA (Fakhouri et al. 2014). The steep decline in physical activity levels observed during adolescence (Troiano et al. 2008) makes it a particularly relevant developmental stage to investigate.

The growing interest in the physical activity habits of youth with autism spectrum disorder (ASD) may be attributed, in part, to the increasing prevalence of ASD, the high rates of overweight and obesity (Broder-Fingert et al. 2014; Curtin et al. 2010; Egan et al. 2013; Hill et al. 2015; Must et al. 2016), and low levels of health-related fitness in this population (Borremans et al. 2010; Kern et al. 2013; Pan et al. 2016; Tyler et al. 2014). The most current evidence indicates that children and adolescents with ASD are not sufficiently active and fall short of meeting the Center for Disease Control's Physical

Activity Guidelines (Bandini et al. 2013; Obrusnikova and Cavalier 2011; Memari et al. 2015; MacDonald et al. 2011). Several studies have found that youth with ASD are less physically active than their typically developing (TD) peers (McCoy et al. 2016; Pan et al. 2016; Tyler et al. 2014), though this finding has not been consistently observed across all age groups (Bandini et al. 2013; Rosser Sandt and Frey 2005). Children with ASD reportedly participate in activities less frequently and with less variety than TD children (Bandini et al. 2013; Little et al. 2014) which may account for some of the differences between groups. Of particular concern are the lower levels of physical activity in older children and adolescents that have been regularly observed in cross-sectional studies among children and adolescents with ASD (MacDonald et al. 2011; Memari et al. 2012; Pan and Frey 2006).

Accelerometers provide objective information about physical activity participation, such as the intensity and duration of activity bouts, and thus enable researchers to measure and describe the activity levels of youth with ASD. However, the quantitative data obtained through accelerometry provide no insight into the nature of the activities being performed. Knowledge of the types and variety of physical activities that children with ASD engage in, as well as the frequency of participation in specific activities, would broaden what is already known about physical activity behaviors in this population. Despite extensive research documenting the physical activity habits of TD children and repeated calls to examine the physical activity needs of children with disabilities (Rimmer and Rowland 2008; Sorensen and Zarrett 2014), a more complete characterization of the physical activity behavior of this population is essential to inform and improve interventions. The purpose of the present study was to extend the physical activity research involving adolescents with ASD by assessing and characterizing their participation in moderate and vigorous intensity activity. We developed a questionnaire to query adolescents and their parents about the types and frequencies of activities they engaged in to provide a more complete account of their physical activity behaviors. As such, the aims of this study were to examine and compare the following among adolescents with ASD and TD adolescents: (1) time spent in moderate and vigorous intensity physical activity; and (2) the types and frequencies of physical activities performed. We hypothesized that adolescents with ASD would spend significantly less time in physical activity compared to TD adolescents and that they would participate in significantly fewer physical activities at lower frequencies. We further hypothesized that the differences would be greater in older adolescents compared with younger adolescents.

Method

Participant Recruitment and Enrollment

This study was part of a larger study that examined physical activity levels and correlates among adolescents with intellectual disabilities and TD adolescents. Additional grant support provided a unique opportunity to expand our sample to also include youth with ASD, thereby expediting research on physical activity participation in this population of youth. A sample of 30 adolescents with ASD was proposed for this sub-study. We recruited adolescents with ASD ages 13–21 years and TD adolescents ages 13–18 years to participate in the study. The upper age limit was higher in the ASD group because youth with disabilities are permitted to remain in school until their 22nd birthday. Participants were required to be in good health and were excluded from participating if they had any of the following conditions: chronic illness such as heart disease or cancer; physical disability such as cerebral palsy, spina bifida, or muscular dystrophy; schizophrenia or psychosis; or an acute or chronic injury at the time of screening that would limit typical physical activity. Adolescents were also required to be verbally communicative without an assistive device and to reside at home with a parent.

We recruited participants with ASD from several sources, including special education schools, disability service agencies, community organizations, Special Olympics, special education parent advisory councils, Craigslist™, newspapers, an in-house database of participants from previous studies, and with the assistance of the Interactive Autism Network (IAN) Research Database at the Kennedy Krieger Institute and Johns Hopkins School of Medicine. We recruited TD adolescents through many of these same outlets as well as general community-based agencies and organizations. Recruitment materials were distributed via email, mail, listservs, websites, bulletin boards, and in person at community events and conferences. Interested parents or adolescents contacted the study coordinator directly.

The screening and enrollment protocol entailed an initial telephone interview with a parent to determine the eligibility of the adolescent to participate in the study. Parents of adolescents with ASD also completed the Autistic Diagnostic Interview, Revised (ADI-R) (Rutter et al. 2003) to verify their child's autism status prior to the study visit. For inclusion in the study, adolescents needed to meet or exceed the cut-off scores in the Reciprocal Social Interactions domain (cut-off score is 10) and at least one additional domain (i.e., Language/Communication [cut-off score is 8] and/or Restrictive, Repetitive, and Stereotyped Behaviors and Interests [cut-off score is 3]) on the ADI-R. Adolescents with ASD also completed the Kaufman Brief Intelligence Test, 2nd edition (KBIT-2; Kaufman and Kaufman 2004),

and their parents completed the Vineland Adaptive Behavior Scales II (VABS-II; Sparrow et al. 2005) to assess their child's level of adaptive functioning. We used this information to characterize the sample.

Informed consent was obtained during the study visit from a parent and those adolescents 18 years of age and older who were under their own guardianship. Adolescents who were younger than 18 years and those who were under parental guardianship indicated their willingness to participate by signing an assent form. Assent forms included simple explanations that were read aloud to the adolescents in the presence of a parent.

The study protocol and all materials were approved by the University of Massachusetts Medical School Institutional Review Board for the protection of human subjects.

Physical Activity Assessment

Accelerometry

Actical® accelerometers were used to measure physical activity levels. Participants were asked to wear the accelerometer for 7 days, including 5 weekdays and 2 weekend days. The Actical® uses a "piezoelectric accelerometer", or motion sensor, that integrates the degree and intensity of motion and produces a voltage output signal whose magnitude is recorded as activity counts. The validity of accelerometers is well-established and these monitors have been used in previous studies to objectively measure physical activity in children and adolescents with developmental disabilities, including ASD (e.g., Bandini et al. 2013; Kim and Yun 2009; Memari et al. 2013; Tyler et al. 2014). The accelerometer was secured to a belt and positioned over the hip. We instructed participants to wear the monitor for all waking hours except when swimming, showering, or bathing. We provided families with a log in which to record the wear time of the accelerometer and any times that it was removed during the day. Additionally, we asked families to record if the day was atypical (e.g., the participant was sick, missed school, or participated in an unusual activity). Data from the accelerometer were compared to the recorded times in the log to determine wear time and non-wear time. To be included in the analyses, participants were required to wear the accelerometer for a minimum of three "typical" weekdays and one weekend day for ≥600 min/day (Wolff-Hughes et al. 2014, 2016).

Activity counts from the accelerometer were recorded over 15-second epochs and were used to estimate time spent in MVPA based on established cut-points for physical activity intensity (Puyau et al. 2004). Physical activity that was of moderate and vigorous intensity was evaluated as a composite variable. We examined total activity counts and minutes of MVPA per day across weekdays and weekend days. We computed the total average daily physical activity (in activity counts and MVPA min/day) from a weighted average of weekday and weekend activity data [(5 × weekday average + 2 × weekend average)/7].

Questionnaire

We developed a questionnaire for this study to gather information on the type and frequency of physical activities that adolescents performed over the past year. The questionnaire was designed to be verbally administered to adolescents and one of their parents as a structured interview. Since some youth with ASD may find estimating their physical activity participation over the past year to be difficult, we decided to interview parents and adolescents together so parents could assist adolescents to recall their participation and estimate the frequency. In order to be consistent, we used the same procedure for both youth with ASD and TD youth. A trained interviewer engaged both the adolescent and their parent when asking questions about the types of physical activities performed and the frequency of participation. The questions were asked to the adolescents and parents together so that they could deliberate and arrive at an agreement on the most accurate estimates of physical activity participation. In the event that a parent and adolescent responded differently to a question and/or there was uncertainty or disagreement on the type and/or frequency of an activity performed by the adolescent, the interviewer assisted them by asking clarification questions so that they could reach consensus on the most accurate estimate.

The questionnaire asked about activities that were performed outside of school time including after school, weekends, and during the summer (not physical education class). Examples of activities included basketball, dancing, gymnastics, karate, running/jogging, swimming, active video gaming, cheerleading, soccer, and walking/hiking. The questionnaire included a two-part item for each of the 29 activities. We first asked participants whether or not they "ever" participated in the activity in the past year. For example, "Did you ever play/do kickball in the last year?" A picture of a person playing kickball was shown to participants when the question was asked. This visual support was provided in an effort to help participants understand the activity in question. If the participant answered "yes", we then asked if they performed that activity with a frequency of 12 or more times in the past year. The aim was to determine which activities the adolescent had participated in on a regular basis (i.e., an average of 1 time/month). Participants who responded "yes" that they had performed the activity 12 or more times were asked to provide the frequency of their participation on a month-by-month basis. Specifically, the interviewer asked, "In which months last year did you play kickball?" (for example). For each month

that the participant did the activity, the question was asked, "How often did you play kickball in September?" (for example). The frequency response options were: 1 time/month, 2–3 times/month, 1 time/week, 2–3 times/week, 4–6 times/week, and ≥1 time/day. A printed card with these response options was provided to participants for reference, though the interviewer also repeated questions and response choices as needed. Once the participants reported on all 29 activities, the interviewer asked them to report on any other physical activities that they performed in the last year that were not on the list.

Test–retest reliability of the questionnaire was assessed by comparing the responses from a subset of participants (n = 15 with ASD; n = 20 TD) who repeated the interview within 14–21 days using a correlation coefficient. The reliability of monthly physical activity frequency was good in both groups ($r = 0.63$, $p < 0.05$ for participants with ASD; $r = 0.75$, $p < 0.01$ for TD participants). Similar correlation coefficients were observed for the variable representing the number of activities done ≥ 12 times/year ($r = 0.66$, $p < 0.01$ for participants with ASD; $r = 0.85$, $p < 0.01$ for TD participants).

We only included activities that were performed with a frequency of ≥12 times/year (i.e., on a regular basis) in the analyses. We converted the frequency response categories to numeric monthly estimates: 1 time/month = 1; 2–3 times/month = 2.5; 1 time/week = 4.35; 2–3 times/week = 10.88; 4–6 times/week = 21.75; ≥1 time/day or more = 30.45. We calculated total monthly physical activity frequency by summing the frequency of participation in all regular activities for each month, and then dividing that number by 12. We also calculated the number of activities each participant engaged in ≥ 12 times/year to obtain an estimate of the variety of activities.

Statistical Analyses

Participants who did not meet study criteria for wearing the accelerometer were not included in analyses based on accelerometry, but were retained for analyses of physical activity participation measured by questionnaire. Although adolescents with ASD wore the accelerometer for fewer minutes than TD adolescents on weekdays (858 min vs. 917 min, $p < 0.001$) and as a daily weighted average (831 min vs. 882 min, $p < 0.001$), there were no significant correlations between wear time and physical activity counts or minutes in either group. Therefore, wear time was not considered confounding and was not adjusted for in the analyses.

We compared demographic characteristics between the groups using independent sample t-tests for continuous variables and Chi square tests for categorical variables. We also used a Chi square test to assess whether the proportion of youth meeting Physical Activity Guidelines differed between the two groups. A series of linear regression analyses were conducted for physical activity outcome variables based on accelerometry (total counts and MVPA min/week on weekdays, weekend days and as a weighted weekly average) and physical activity participation from the questionnaire (frequency of activities and number of regular activities). These regression models were adjusted for age and sex. Group-by-age (<16 years vs. ≥16 years) and group-by-sex interactions were evaluated for each outcome. All analyses were conducted using SAS version 9.2 and IBM SPSS Statistics 20. P-values less than 0.05 were considered statistically significant. To describe the individual activities preferred by participants with ASD and TD participants, we calculated the percentage of adolescents who reported each activity at least 12 times annually (regular activities), and ranked the top 10 for each group.

Results

Thirty-five adolescents with ASD and 60 TD adolescents were enrolled in the study. Adolescents with ASD were significantly more likely to be male compared to TD adolescents (83% vs. 60%, $p = 0.02$, Table 1) and were slightly older (15.9 vs. 15.3 years, $p = 0.06$). Mean scores on the KBIT-2 and VABS-II for adolescents with ASD were 78.0 ($SD = 28.0$) and 62.5 ($SD = 12.1$), respectively. Eighteen of the 35 (51.4%) adolescents with ASD also had an intellectual disability (IQ score of ≤75). The sample was predominantly white and most of the parents in both groups were college-educated.

Table 1 Characteristics of TD adolescents and adolescents with ASD

	TD Adolescents (n = 60)	Adolescents with ASD (n = 35)	p value
	Mean (SD) or %	Mean (SD) or %	
Age (years)	15.3 (1.5)	15.9 (1.7)	0.06
Male (%)	60%	83%	0.02
Race/ethnicity, (%) white	68%	80%	0.22
At least 1 parent with college degree	82%	71%	0.22

Accelerometer Data

Of the adolescents enrolled in the study, 29 (83%) adolescents with ASD and 55 (92%) TD adolescents met the criteria for wear time and were included in the accelerometry analyses (no significant group differences; $p > 0.05$ by Chi square). Accelerometer data presented in Table 2 include total activity counts and absolute time spent in MVPA, adjusted for age and sex. Total activity counts were significantly lower among adolescents with ASD compared to TD adolescents on weekdays, weekends, and as a daily weighted average. Differences also existed for time spent in MVPA; adolescents with ASD spent an average of about 29 min/day in MVPA compared to 50 min/day among TD adolescents ($p < 0.001$). Adolescents with ASD also spent significantly less time in MVPA on both weekdays and weekend days. On average, participants in both groups were unlikely to meet the recommendation of at least 60 min/day of MVPA. Fewer adolescents with ASD met the guideline than TD adolescents, but this difference was not statistically significant. (14 vs. 29%, respectively; $p > 0.05$ by Chi square).

We did not observe any group-by-sex interactions, but did observe a significant group-by-age interaction for the accelerometry outcomes. To explore the nature of the influence of age by group, we stratified the sample at the median age of the sample which was 16 years (Table 2). For all outcomes, total, weekday, and weekend day accelerometry counts and MVPA minutes, levels for TD adolescents were greater than for their peers with ASD. However, compared to adolescents ≥16 years, the differences by group for total counts and MVPA minutes (overall, weekday and weekend day) were far greater for adolescents <16 years and were statistically different. For adolescents ≥ 16 years, differences were in the same direction, but smaller and non-significant.

Questionnaire Data

Physical Activity Frequency

Questionnaire data are presented in Table 3. After models were adjusted for age and sex, there was no statistically significant difference in the frequency of physical activity participation between the groups. Adolescents with ASD participated in various activities an average of 39.9 times/month, compared to TD children at 40.3 times/month ($p = 0.95$). Regarding the variety of activities performed on a regular basis, adolescents with ASD had an average of 5.5 activities that they engaged in ≥12 times/year, compared to TD adolescents who reported an average of 6.6 activities that they engaged in ≥12 times/year ($p = 0.09$).

We observed a significant group-by-age interaction in the number of regular activities that participants reported they had engaged in ≥12 times over the past year. Among participants younger than 16 years of age, there was a significant difference in the number of regular activities between the groups; adolescents with ASD engaged in significantly fewer regular activities compared to TD adolescents (5.3 vs. 7.1, $p = 0.03$). Among adolescents aged 16 years or older, however, the number of regular activities did not differ (5.7 vs. 5.6, $p = 0.88$).

Type of Physical Activities

In addition to the overall number of physical activities performed on a regular basis, we examined the distribution of individual activities within each group (Fig. 1). Among the TD adolescents, the 10 activities that they reported engaging in most frequently were (in rank order): running/jogging, active video gaming, walking/hiking, swimming, basketball, bicycling, dancing, football, weightlifting, and baseball/softball. There was considerable overlap between these physical activities performed by the TD adolescents and activities most frequently performed by adolescents with ASD. The top seven activities were the same for adolescents with ASD although the order of distribution was slightly different (see Fig. 1). The 10 most commonly reported regular activities among adolescents with ASD were (in order): walking/hiking, swimming, active video gaming, basketball, running/jogging, dancing, bicycling, yoga, kickball, and baseball/softball. Active video gaming and walking/hiking were among the top three most frequently performed activities for both groups.

Discussion

One aim of this study was to compare time spent in physical activity among adolescents with ASD and TD adolescents ages 13–21 years using accelerometry and to characterize the type and frequency of activity modalities. Overall, adolescents with ASD accumulated approximately 20 min/day less of MVPA than TD adolescents, were significantly less active than their TD peers on both weekdays and weekend days, and fell far short of the 60 min/day recommendation in the U.S. Physical Activity Guidelines. Among younger adolescents, but not older ones, the variety of activities was greater among TD adolescents compared to adolescents with ASD.

Our findings are consistent with other studies that have objectively examined physical activity levels of adolescents with ASD. In a recent study of Taiwanese adolescents with and without ASD ages 12–17 years, participants with ASD accumulated an average of 64 min/day of MVPA on

Table 2 Accelerometer-measured physical activity level among TD adolescents and adolescents with ASD

	Daily weighted average				Weekdays				Weekend days			
	TD mean (n = 55)	ASD mean (n = 29)	Mean difference (95% CI)	p value	TD Mean (n = 55)	ASD Mean (n = 29)	Mean difference (95% CI)	p value	TD mean (n = 55)	ASD mean (n = 29)	Mean difference (95% CI)	p value
Total activity counts												
Overall[a]	243,368	174,359	69,009 (17,880 to 120,138)	0.009	259,690	187,748	71,941 (17,674 to 126,209)	0.01	202,563	140,886	61,678 (2,935 to 120,420)	0.04
<16 years[b]	248,992	159,266	89,727 (27,060 to 152,393)	0.006	262,119	174,751	87,368 (21,452 to 153,284)	0.01	216,176	120,553	95,623 (20,243 to 171,002)	0.01
≥16 years[c]	225,940	197,512	28,429 (−67,661 to 124,518)	0.55	248,158	210,651	37,507 (−67,009 to 142,023)	0.47	170,396	164,663	5,733 (−95,782 to 107,248)	0.91
Time in MVPA (min)												
Overall[a]	50.0	29.1	20.9 (8.6 to 33.1)	0.001	54.6	33.5	21.1 (7.8 to 34.4)	0.002	38.4	18.1	20.3 (6.6 to 33.9)	0.004
<16 years[b]	51.1	25.6	25.5 (10.5 to 40.4)	0.001	55.2	31.0	24.2 (8.2 to 40.2)	0.004	40.9	12.2	28.7 (11.2 to 46.2)	0.002
≥16 years[c]	46.3	34.7	11.5 (−11.5 to 34.6)	0.31	51.8	38.5	13.3 (−12.7 to 39.2)	0.30	32.5	25.3	7.2 (−16.5 to 30.8)	0.54

Overall models adjusted for age and sex; age-stratified model adjusted for sex

[a] n = 55 TD, 29 ASD

[b] n = 39 TD, 16 ASD

[c] n = 16 TD, 13 ASD

Table 3 Frequency of participation in physical activities among TD adolescents and adolescents with ASD

	TD mean	ASD mean	Mean difference (95% CI)	p value
Frequency of activities (times/month)				
Overall[a]	40.3	39.9	0.41 (−11.7 to 12.6)	0.95
<16 years[b]	40.3	42.2	−1.9 (−16.9 to 13.1)	0.80
≥16 years[c]	41.6	36.6	4.9 (−17.2 to 27.1)	0.65
Number of regular activities**				
Overall[a]	6.6	5.5	1.1 (−0.19 to 2.4)	0.09
<16 years[b]	7.1	5.3	1.8 (0.23 to 3.5)	0.03
≥16 years[c]	5.7	5.6	0.17 (−2.2 to 2.6)	0.88

Least square means adjusted for age and sex

**Activities performed ≥12 times/year

[a]n = 59 TD, 35 ASD

[b]n = 41 TD,17 ASD

[c]n = 18TD, 18 ASD

weekdays and 63 min/day on weekend days, and TD participants averaged 91 min/day and 55 min/day on weekdays and weekend days, respectively (Pan et al. 2016). Although the duration of MVPA in both groups was higher compared to the participants in our study, adolescents with ASD engaged in significantly less MVPA compared to TD adolescents, consistent with the findings of the present study. Tyler et al. (2014) also reported that children ages 9–18 years with ASD spent significantly less time in MVPA compared to TD children. Their participants accumulated sufficient physical activity to meet the Physical Activity Guidelines, unlike the adolescents in the present study and in a small study by Pan (2006). In our prior study of physical activity in children with ASD ages 3–11 years, we did not find differences in time spent in, or intensity of, physical activity between children with ASD and TD children (Bandini et al. 2013). Likewise, Rosser et al. (2005) did not observe differences in physical activity levels between children with ASD and TD children. In the current study, when we stratified by age, we found significant differences in MVPA between groups only for adolescents less than 16 years of age. In this younger group of adolescents, TD youth accumulated about 25 min/day more than those with ASD. Unlike Pan and Frey's (2006) study where youth with ASD in elementary school were more active than those in middle and high school, the older adolescents (≥16 years) with ASD in this study accumulated about 9 min/day of MVPA more than the younger adolescents (<16 years) with ASD. We found that this differential in time spent in MVPA between children with ASD and TD children by age group was more marked on the weekends. Among the TD adolescents, the younger age group had more minutes/day of MVPA than the older age group. More research in this area is needed to fully characterize the activity habits of adolescents with ASD compared to TD adolescents, and to examine subgroups within a larger sample.

Our findings that time spent in MVPA was considerably lower on weekend days compared to weekdays in both groups of adolescents is consistent with previous

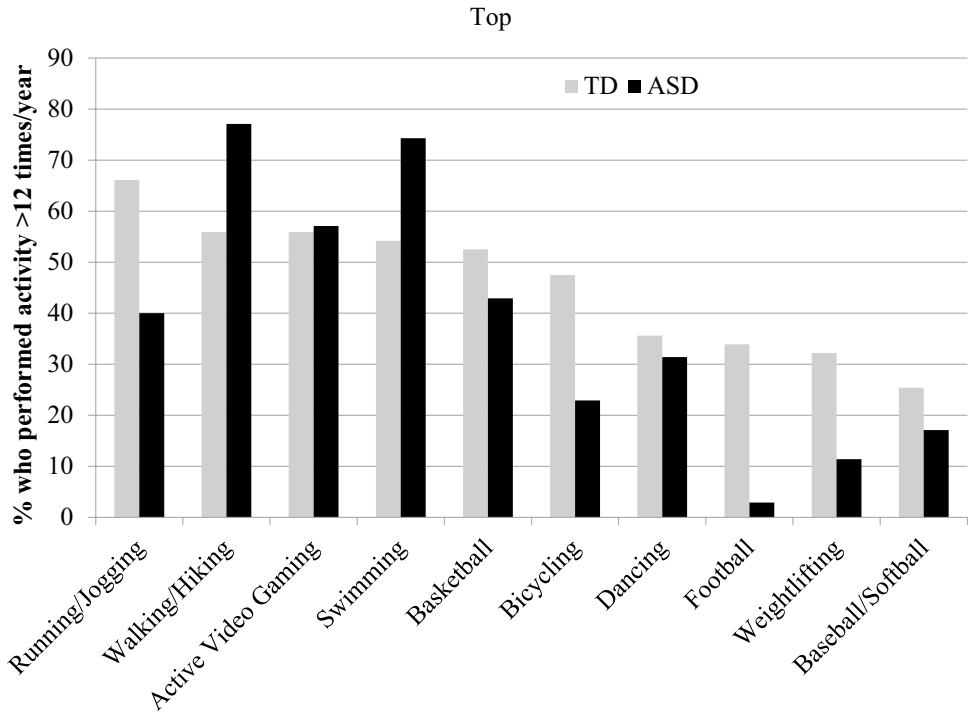

Fig. 1 Most commonly reported physical activities by group

physical activity studies of TD children. It is notable that the younger adolescents with ASD (<16 years of age) accumulated only an average of 12 min/day of MVPA on weekend days, significantly less than their TD peers (40.9 min/day). Pan et al. (2016) also reported lower physical activity levels on weekends compared to weekdays in adolescents with ASD. School-related activities including physical education classes, recess, and active transport to and from school may have contributed to the higher activity levels on weekdays for children with ASD.

An important goal of this study was to obtain a better understanding of the physical activity participation of adolescents with ASD through examining the type and variety of activities that they perform. This characterization of physical activity behavior can build upon the objective data that exist, and may provide a more complete picture of the nature of their activity participation. Srinivasan et al. (2014) noted the limited evidence on exercise interventions for individuals with ASD, and that the existing evidence for how best to intervene is weak. Our work was intended to be a step toward informing physical activity interventions for youth with ASD through expanding our understanding of the sorts of activities that they may prefer. Affording adolescents with ASD the opportunity to report on their own activities, instead of relying on parent/proxy reporting, was also an important element of the study (Curtin et al. 2015).

Contrary to our hypothesis, we found that adolescents with ASD and TD adolescents engage in a similar array of activities; the number of regular physical activities was not different between groups nor was the overall frequency of participation. Additionally, the physical activities that adolescents with ASD performed most frequently were very similar to those of TD adolescents. Specifically, adolescents in both groups reported that active video gaming, walking/hiking, swimming, running/jogging, bicycling, dance, and basketball were among their most frequently performed activities. This finding suggests that adolescents with and without ASD are more similar than different in their choices of physical activities; this supports the potential of inclusive programming. Although youth with ASD often face unique obstacles to engaging in physical activity and may require additional support (Must et al. 2015), our results imply that they choose to engage in many of the same activities as their TD peers. The context in which adolescents with ASD participate in these reported activities may differ from their peers, including the venues where they participate, with whom they are active, and the degree of activity organization/structure. Thus, their participation may be modified in some way. However, the similar activity preferences hold promise for promoting engagement in existing school- and community-based opportunities that involve TD youth.

Our findings should be considered in light of the study's limitations and strengths. First, there are challenges associated with gathering information about physical activity behavior via self-report questionnaires. We are not aware of any validated questionnaires for this population, including the instrument we used in the current study. Accurate recall of behavior is challenging, and may be particularly difficult for individuals with ASD. In this study, we found that parents of adolescents with ASD provided a great deal of information on the physical activity questionnaire whereas the TD adolescents mostly reported on their own behavior. This discrepancy may have been partially due to the range in cognitive ability among children with ASD, 51.4% of whom had an intellectual disability, which may have affected their understanding of the questions and their ability to estimate the frequency with which they engaged in an activity. This differential source of information could bias our results. Our study was also small and based on a convenience sample. Finally, generalizability may be limited, given that the sample comprised primarily white youth, most of whom were boys. Strengths of our study include extensive characterization of physical activity levels and types, the inclusion of adolescents as respondents, and the use of accelerometry as an objective measure of physical activity.

In conclusion, the present study supports previous work suggesting that youth with ASD acquire significantly less MVPA than their TD counterparts, despite the fact that both groups report similar interests and engagement in different activities. The findings suggest that while adolescents with ASD may be participating in the same number and type of activities, the time spent in these activities at moderate-to-vigorous levels is below that of their TD peers. In this study we were not able to determine the reasons for this; factors such as physical fitness, motor competence, and ability to sustain participation for attentional and persistence reasons may be contributory, and thus warrant further investigation. Supporting the participation of youth with ASD in physical activities that confer health benefits will require finding ways to promote their participation at sufficient intensity levels for extended periods of time. Physical activity providers have an important role in adapting activities and accommodating the needs of youth with ASD so that they may be successful in school- and community-based activities. Working together with parents and youth with ASD to identify enjoyable activities and to determine appropriate modifications will increase the effectiveness of physical activity programs, especially in inclusive settings. Researchers are encouraged to adapt evidence-based interventions that can promote sustained participation in physical activity and to involve support personnel (e.g., families, peers) in meaningful ways when

seeking to advance the research agenda in physical activity promotion among youth with ASD.

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Author Contributions HS conceived of the study and participated in its design and coordination and drafted the manuscript; CC participated in the conception and design of the study and interpretation of the data; AM participated in the design of the study and interpretation of the data; SP participated in the statistical analyses and interpretation of the data; MM participated in the coordination of the study and performed the measurement; LB conceived of the study and participated in its design and coordination. All authors have read and approved the final manuscript.

Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflicts of interest.

Informed consent Informed consent was obtained from all individual participants and a parent included in the study.

Research involving animal and human rights 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. The protocol was approved by the Institutional Review Board.

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