Objectively Measured Physical Activity and Health-Related Physical Fitness in Secondary School-Aged Male Students With Autism Spectrum Disorders

Chien-Yu Pan, Chia-Liang Tsai, Chia-Hua Chu, Ming-Chih Sung, Wei-Ya Ma, Chu-Yang Huang

Background. Recent evidence suggests that childhood obesity is increasing in children with typical development (TD) and in children with autism spectrum disorders (ASD). The associations between physical activity (PA) levels and physical fitness components have not yet been objectively examined in this population but may have clinical implications for the development of secondary health complications.

Objective. The aims of this study were: (1) to compare PA and physical fitness between secondary school-aged male students with ASD and their peers with TD and (2) to assess possible interrelationships between PA and physical fitness levels in each group.

Design. This was a cross-sectional study.

Methods. Physical activity was recorded every 10 seconds by using accelerometry in 70 male students with (n=35) and without (n=35) ASD for up to 5 weekdays and 2 weekend days. The Brockport Physical Fitness Test was used to assess physical fitness.

Results. The primary findings were: (1) participants with ASD were less physically active overall and engaged in moderate-to-vigorous PA for a lower percentage of time compared with participants with TD during weekdays; (2) participants with ASD had significantly lower scores on all physical fitness measures, except body composition; and (3) group-dependent relationships existed between physical fitness profiles and PA levels.

Limitations. The study design limits causal inference from the results.

Conclusion. Specific interventions for maximizing PA and physical fitness levels in secondary school-aged male students with ASD are urgently needed.

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Evidence for the importance of daily physical activity (PA) for the health of youth is increasing.[1] The increased levels of PA are likely to enhance cardiorespiratory fitness and cardiometabolic health.[2] Because of the importance of PA to the physical fitness and health of youth, the attention on monitoring the adherence of youth to PA guidelines has increased. The consensus recommendation is that youth should participate in moderate-to-vigorous PA (MVPA) for 60 minutes or more per day on most days of the week.[1,3] Furthermore, PA patterns track from childhood into adolescence and from adolescence into adulthood.[4] Therefore, considerable research effort has been devoted to comprehensively understanding the PA of youth as a modifiable lifestyle behavior. However, little information is available on PA and physical fitness for youth with autism spectrum disorders (ASD). Autism spectrum disorders are characterized by impairments in social interaction and communication skills and restrictive interests.[5] Various researchers have noted differences in the motor skills of school-aged youth with ASD.[6–9] These social, behavioral, and motor difficulties may interfere with various PA opportunities and, therefore, put such youth at risk of not achieving sufficient PA and not maintaining physical fitness.

Obesity has become a major health concern in youth worldwide, including youth with ASD. Although the prevalence of obesity in youth with ASD may not have surpassed the norms from the 2003–2004 National Survey of Children's Health, statistics suggest that youth with ASD are 40% more likely to be overweight and obese compared with their peers with TD.[10] Recent research assessed the body mass index (BMI) status of youth with ASD and compared it with that of the general population by using 2007–2008 National Health and Nutrition Examination Survey (NHANES) data. This research suggested that the prevalence of obesity in youth with ASD may variably differ with age; children aged 2 to 5 years with ASD had a higher prevalence of overweight and obesity, and children aged 5 to 11 years with ASD had a higher prevalence of underweight compared with the NHANES age-matched controls.[11] Although factors that affect obesity in youth with ASD may include dietary habits, medications, reduced opportunity for PA, and increased interest in sedentary activities, the positive influence of PA cannot be overlooked. Memari et al[12] examined PA patterns and determinant factors in youth with ASD and found that, overall, PA was substantially lower in the group with obesity than in the normal-weight group and that age was correlated with a decrease in PA in youth with ASD. Because PA is crucial in the prevention of obesity, understanding the PA of youth with ASD would enable targeted obesity prevention and treatment.

Although several studies have characterized PA in youth with ASD by using accelerometry, they have largely been limited by small sample sizes, various age ranges of the participants, and a lack of a comparison group. Bandini et al[13] compared PA in children with ASD with children with TD aged 3 to 11 years. The results indicated that children with ASD and children with TD engaged in similar levels of PA (overall PA and MVPA) over the week (7 consecutive days), but children with ASD spent less time engaging in moderate PA than children with TD did on weekdays. Only 23% of the participants with ASD met the criteria for at least 60 minutes of daily MVPA. Rosser Sandt and Frey[14] did not observe differences in daily PA levels or in any PA setting (physical education, recess, and after school) between children with ASD and children with TD aged 5 to 12 years. They observed no day-of-week PA differences in children with ASD and children with TD, and 67% of the children with ASD engaged in at least 60 minutes of MVPA daily. Memari et al[12] examined PA patterns in youth with ASD aged 7 to 14 years and found that PA levels during weekdays and weekends did not significantly differ; however, youth with ASD were considerably less active in school compared with after school. Pan and Frey[15] investigated PA patterns in youth with ASD aged 10 to 19 years and observed no differences in overall PA or MVPA regarding day-of-week and time-of-day variability according to the grade level of the participants. Physical activity decreased with an increase in age, and only 47% of the youth with ASD accumulated the recommended daily 60 minutes of MVPA. MacDonald et al[16] assessed the MVPA of a group of 72 youth with ASD between the ages of 9 and 18 years and determined that both the younger (9–11 years) and older (12–18 years) youth with ASD met the minimal recommendation of 60 minutes of daily MVPA. Their study results also revealed declines in PA as the age of youth with ASD increased.[16] Because PA decreases in older youth with ASD, the need to understand PA in this population has become increasingly crucial in the development, implementation, and evaluation of interventions targeting PA.

The level of PA is considered a behavioral factor that influences physical fitness, which is often divided into aerobic fitness (test for cardiorespiratory endurance), musculoskeletal fitness (test for muscular strength and endurance), flexibility (test for range of motion), and body composition (test for the degree of leanness of the body).[17] The relationship also may be correct in reverse, that is, youth who are fit are often more active than youth who are less fit. However, data regarding the PA and physical fitness levels of youth with ASD are lacking, and there is no published study that has explored this relationship. Borremans et al[18] compared the PA level and physical fitness profile of adolescents with and without Asperger syndrome and found that adolescents with Asperger syndrome were less physically active and scored lower on all physical fitness subtests compared with adolescents with TD. Tyler et al[19] investigated the PA and fitness profiles of youths (aged 9–18 years) with and without ASD and observed that youth with ASD exhibited substantially less PA and were less physically fit in the strength domain compared with their peers with TD. However, youth with ASD exhibited similar aerobic fitness, body composition, and flexibility as their peers with TD. Unfortunately, that study did not explore the relationship between PA and physical fitness.[18,19]

The primary aims of this study were: (1) to compare components of physical fitness and objectively measured PA levels between Taiwanese secondary school-aged male students with ASD and their peers with TD and (2) to assess the interrelationships between PA and physical fitness within each group. Taiwan, officially the Republic of China, is a sovereign state in East Asia. Students' PA and physical fitness levels are particularly crucial because the majority of Taiwanese families live in small apartments in high-rise buildings, and space for PA in schools and communities is limited. Because previous studies have been conducted in the West, this study may increase our understanding of PA and physical fitness in the ASD population across cultures. We further investigated any differences in physical fitness between participants with and without ASD who did and did not meet the daily MVPA recommendation because the accumulated moderate intensity of PA is critical in influencing a person's physical fitness. We hypothesized: (1) that participants with ASD would demonstrate lower levels of physical fitness, as measured using the Brockport Physical Fitness Test (BPFT),[20] and lower levels of PA (ie, percentage of time spent engaging in MVPA [MVPA%] and overall PA [counts per minute (cpm)]), as measured using accelerometry, compared with participants with TD; (2) that positive associations between PA (MVPA% and counts per minute) and physical fitness (aerobic functioning, musculoskeletal fitness, and flexibility) and negative associations between PA (MVPA% and counts per minute) and BMI would exist in each group; and (3) that both groups of participants with ASD and participants with TD who met the daily 60 minutes of MVPA recommendation would be more physically fit than the other 2 groups of participants with ASD and participants with TD who did not.

Method

Participants

A convenience sample of 70 male students with (n=35) and without (n=35) ASD, aged 12 to 17 years, from 35 secondary schools in Taiwan volunteered to participate in the study. Only male students were included in the study because of (1) sex differences in PA and physical fitness levels,[21] (2) sex ratio disparities in ASD (approximately 4:1 male: female),[22] and (3) possible sex-specific ASD for phenotypes.[23] All participants with ASD were diagnosed since they were toddlers and received a new clinical diagnosis within 2 years before the present study began according to the *Diagnostic and Statistical Manual of Mental Disorders, Text Revision*, 4th ed,[5] criteria for ASD from a child psychiatrist or hospital physician.[24] The diagnoses included 10 Asperger syndrome and 25 mild autistic disorder diagnoses. The level of severity (mild, moderate, severe, and very severe) was based on social-adaptive functioning in skill areas and in language comprehension and expression.[25] Each mild autistic disorder diagnosis was identified on the participant's disability card issued by the local government. Based on the psychiatrist's or physician's diagnosis statement, none of the participants were identified with co-occurring intellectual disability, and none exhibited orthopedic dysfunction that could interfere with their physical movements. They received no treatment with psychotropic medications (eg, antidepressants, medications used to treat attention deficit hyperactivity disorder, anti-anxiety medications, and mood stabilizers) that alter activity. In addition to the formal diagnosis made by the psychiatrist or physician, parent ratings were collected and confirmed through parental reports with the use of the traditional Mandarin version of the Autism Behavior Checklist[26] and the Autism/Asperger Behavior Rating Scale[27] to screen for autism and Asperger behaviors. All participants with ASD were usually assigned to the resource room (ie, a classroom where participants with ASD were given direct, specialized instruction and academic remediation as individuals or in groups) on a regular basis while continuing their other studies in regular classes during most of each school day. They attended inclusive schools since first grade and typically lived at home.

The TD group (control group) consisted of 35 age-matched male students who were recruited from the same secondary schools as the students with ASD. The participants in the control group demonstrated no physical or mental disabilities, as determined using a brief questionnaire completed by parents or caretakers. All participants resided in the same geographical area of high social and economic deprivation in a large urban city (N=2,777,773, population density=942 people per square kilometer, family income=NT$92,282 [US$3,076] per month, 40% had received high education [junior college and above], 4% were unemployed).[28–30]

Study Design

Analysis of the PA and physical fitness data among participants was conducted using a cross-sectional design.

Instruments

Physical activity. Physical activity levels were assessed using the uniaxial GT1M (ActiGraph, Pensacola, Florida), an accelerometer that measures the vertical acceleration of human motion and is widely accepted as a valid instrument for assessing PA in youth.[31] The accelerometers were programmed to collect data in 10-second intervals. Because the most appropriate accelerometer cutoff point for PA assessment in youth has not been conclusively determined,[32] the age-specific count thresholds in 1-minute epochs corresponding to those in MVPA levels (≥3 metabolic equivalents) in youth were used[33] to compare these data with data from previous studies on youth with ASD.[14,15] Thus, the appropriate age-specific count cutoffs were divided by 6 to accommodate the 10-second epoch length. One example of age-specific count cutoffs was that PA at an MVPA intensity value ranged from ≥211 cpm (ie, 1,263/6=211) for 12-year-olds to ≥379 cpm (ie, 2,274/6=379) for 18-year-olds.[33] All the school programs were comparable in terms of duration. Because of the differences in the daily total monitoring length (ie, wearing time), the relative (percentage) time spent engaging in the total amount of PA (in counts per minute) and in MVPA (MVPA%) were calculated and used in the subsequent analyses. The counts per minute was calculated by summing the counts for all weekdays and weekend days and dividing the minutes of total monitoring time. The MVPA% was calculated by summing the MVPA minutes for all weekdays and weekend days and dividing the minutes of total monitoring time.

Physical fitness. The BPFT[20] was used to assess physical fitness components. The BPFT is a health-related, criterion-referenced physical fitness test for youth aged 10 to 17 years, and the BPFT manual includes separate instructions for youth with and without disabilities. The validity of the BPFT was determined by confirming the concurrent, construct, and content validity of each item for each disability involved.[20]

For this study, the following physiological assessments included in the BPFT were conducted on all participants: (1) the 20-m Progressive Aerobic Cardiovascular Endurance Run (PACER), for assessing aerobic functioning; (2) the isometric push-up test, for assessing upper body muscular strength and endurance; (3) the curl-up test, for assessing abdominal muscular strength and endurance; and (4) the back-saver sit-and-reach test, for assessing lower body flexibility. The raw scores were used for data analysis.

In the PACER test, the participants were instructed to run as long as possible back and forth across a 20-m distance at a specified pace that was progressively increased each minute. The number of acceptable laps completed was determined by excluding the data of when the participant could not keep pace with the signal produced by a tape for 2 consecutive laps or when the participant withdrew from the test. The PACER test has demonstrated acceptable concurrent validity and criterion-referenced validity for measuring and estimating maximal oxygen uptake.[34]

Upper body muscular strength and endurance were measured using the isometric push-up test, which was scored as the participants attempted to sustain a raised push-up position for up to 40 seconds. The participants assumed a front-leaning rest position with the hands directly below the shoulders, arms extended, the whole body in a straight line, and toes touching the floor. Scoring was terminated at 40 seconds or when the correct front-leaning rest position was no longer held.

Abdominal muscular strength and endurance were measured using the curl-up test, in which the participants completed as many sit-ups as possible at a rate of 1 curl every 3 seconds. All participants began by lying in a supine position while maintaining 140 degrees of knee flexion, with their feet placed flat on the floor and their legs held slightly apart. Their outstretched arms were held parallel to their trunk, with their palms facing downward and their fingers outstretched. They contracted their abdominal musculature until their hands had traveled along the measuring strip below their knees. When their fingertips reached the opposite edge of the measuring strip, they returned their shoulders to the mat in a controlled movement. The test was terminated at 75 curl-ups or when the participant was no longer able to perform curl-ups by using the appropriate form.

Flexibility was measured using the back-saver sit-and-reach test, which was scored as the participants reached the most distant point on the ruler with their fingertips. A custom-made sit-and-reach box (30 cm high × 30 cm wide) was used, with a measuring scale marked at the level of the feet. The participants sat with one leg straight and the other leg bent, with the foot of the bent leg placed next to the knee of the straight leg. The arms of the participants were extended forward over the measuring scale with their palms facing downward, one on top of the other. The participants reached directly forward with both hands along the scale toward the sit-and-reach box and performed 4 reaching repetitions, holding the final reach position for at least 1 second. Following the initial set of sit-and-reach measurements, the participants switched leg positions, and a second set of sit-and-reach measurements was collected.

Procedure

Parental consent and student assent were obtained for all the participants. Heights and weights were measured in a private setting in which participants wore light clothing and no shoes. Body mass index was determined by dividing the body mass in kilograms by the stature in meters squared (kg/m^2).

Physical activity. Prior to the measurements, the participants were instructed in attaching the accelerometer (at the right-hand side of the waist), removing it (only during showering, bathing, swimming, and sleeping), and reattaching it each morning upon awakening and dressing. They also were instructed to maintain their normal levels of PA and not to tamper with the accelerometer during the monitoring period.

Consistent with previous studies, the accelerometers were placed on the right-hand side of the waist of the participants by using elastic belts for 7 consecutive days, except during activities in water.[14,15] Participants were given a simple log to record when they put on the ActiGraph each morning and the time they removed it each evening, and they were asked to wear the accelerometer for no less than 10 hours a day during data collection. To ensure data completeness and quality, a research assistant collected the accelerometer prior to participants' bedtime every 2 to 3 days during the monitored days and provided another initialized accelerometer for the following days (ie, a behavioral technique to ensure that the participants were wearing the monitor). Data were immediately downloaded and examined (eg, data sheets were reviewed, missing and odd values were queried the next day).

Physical fitness. The BPFT assessment was conducted in a quiet and isolated gymnasium at the primary researcher's university immediately before and after the 7-day PA assessment, in accordance with the manual. The participants were tested individually by research assistants who had been trained in conducting the test protocols. This training was on how to interact with youth with ASD and how to understand behavioral modification techniques to ensure favorable performance on each outcome measure. All research assistants were blinded to the group; they were told that no modifications were imposed on the test items or instructions, and all test instructions should be followed precisely. Each test item was explained and demonstrated before the participants began. If a participant made a procedural error, instructions and demonstrations of the

Table 1.
Physical Activity Measures of Participants[a]

Parameter	ASD Group (n=35)		TD Group (n=35)	
	Weekday	Weekend	Weekday	Weekend
Total monitored length (min/d)	816.54±93.99	747.01±88.31	829.89±94.53	752.80±112.78
MVPA (min/d)	64.23±48.78	63.14±84.00	90.68±49.14	55.78±36.09
Daily average counts per minute	321.29±132.98	284.85±132.31	443.67±191.44	294.85±103.59
MVPA%	7.93±6.06	8.68±12.51	11.03±5.88	7.39±4.66

[a] Data are presented as mean±SD. ASD=autism spectrum disorders, TD=typically developing, MVPA=moderate-to-vigorous physical activity, MVPA%=daily average percentage of time spent in moderate-to-vigorous physical activity.

task were repeated before he made a new attempt. The participants were given verbal encouragement and support throughout the testing procedure to ensure maximal effort for the test. Parents were permitted to observe the assessment and motivate their child during the test with verbal praise and guidance. The duration of the BPFT was approximately 30 minutes per participant.

Data Analysis

The mean (SD) for each variable was calculated separately for participants with and without ASD. For inclusion in the PA analyses, participants were required to wear the accelerometer for a minimum of 10 hours each day for at least 4 weekdays and 1 weekend day. Analysis of variance (ANOVA; 2-way mixed model) was used to calculate group weekday and weekend differences in PA (counts per minute and MVPA%). The post hoc Tukey test or simple main effect of group by day-of-week PA was used when the difference or interaction between factors was statistically significant. Independent sample t tests were used to assess the group differences in each fitness variable. The Pearson correlation coefficient (r) was computed to examine the bivariate relationships between daily average PA (ie, across weekend days and weekdays) and fitness measures. Secondary analyses were conducted using nonparametric Kruskal-Wallis tests because of the small sample size and unbalanced groups to compare physical fitness levels among participants with and without ASD who did and did not satisfy the daily 60-minute MVPA guideline (ie, all participants were split into 4 groups). All statistical analyses were performed using SPSS software, version 18 (SPSS Inc, Chicago, Illinois).

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Results

All the participants completed the study. None of the demographic variables differed (age: $t=-0.41$, $P=.48$; height: $t=-0.45$, $P=.66$; weight: $t=-0.17$, $P=.86$) between participants with ASD (age: 14.55±1.54 years; height: 167.12±7.21 cm; weight: 60.83±12.85 kg; BMI: 21.77±4.72 kg/m^2) and participants with TD (age: 14.81±1.55 years; height: 168.00±9.08 cm; weight: 61.38±14.05 kg; BMI: 21.63±4.12 kg/m^2).

PA in Participants With and Without ASD

All 70 participants in the current study provided at least 4 weekdays and 1 weekend day of at least 10 hours of recorded PA per day. A total of 70% (n=49) of the participants engaged in PA for 2 valid weekend days and 77% (n=54) engaged in PA for 5 valid weekdays, resulting in a total of 453 valid PA registration days. A minimum recording of 10 hours per day was the criterion to accept daily PA data as valid.

Table 1 presents the mean minutes and proportion of time for the participant PA levels during weekdays and weekend days. We observed no differences in the total monitored length between participants with and without ASD during weekdays ($t=-0.59$, $P=.56$) and weekend days ($t=-0.24$, $P=.81$). For participants with ASD, 37% accumulated at least 60 minutes of daily MVPA. For the participants with TD, 60% satisfied the recommended MVPA.

The results of the 2-way analyses of variance with repeated measures on the day of the week (Tab. 2) indicated that significant differences in overall PA (in counts per minute) existed between the

Table 2.
Two-Way Analysis of Variance With Repeated Measures on Day of Week[a]

Parameter	ASD Group	TD Group	P	Weekday	Weekend	P	Group × Day Interaction, P Value
Daily average counts per minute	303.07±20.90	369.26±20.90	.03	382.48±19.70	289.85±14.20	.00	.00
MVPA%	8.30±1.13	9.21±1.13	.57	9.48±0.71	8.04±1.13	.16	.03

[a] Data are presented as mean±standard error unless otherwise specified. ASD=autism spectrum disorders, TD=typically developing, MVPA%=daily average percentage of time spent in moderate-to-vigorous physical activity.

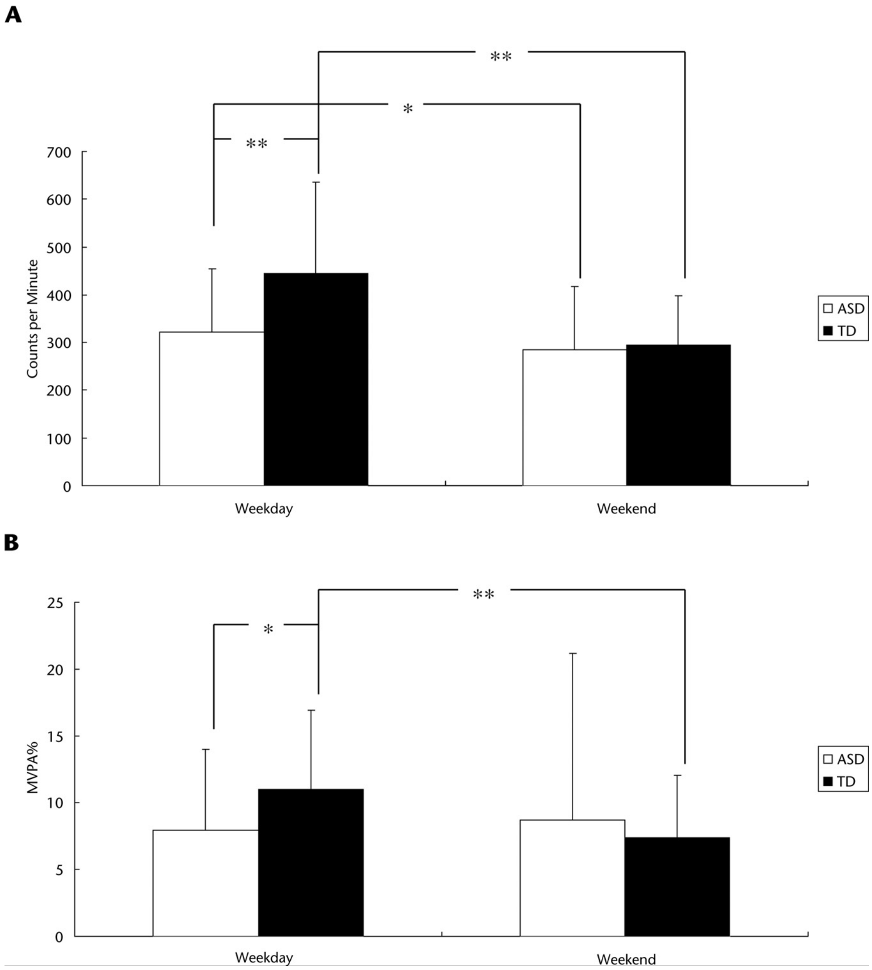

Figure.
(A) Daily average overall physical activity (in daily average counts per minute) according to the participant group (ASD=autism spectrum disorders, TD=typically developing) and the day of the week (weekday, weekend). (B) Daily average percentage of time spent in moderate-to-vigorous physical activity (MVPA%) according to the participant group and the day of the week. * Significant differences at $P<.05$, ** significant differences at $P<.01$.

groups, regardless of the day of the week ($F=5.01$, $P<.05$, partial $\eta^2=.07$, observed power=0.60). Post hoc results revealed that the participants with TD were more active overall than the participants with ASD (counts per minute: +66.19, 369.26 versus 303.07, respectively). In addition, the results of the mixed 2-way ANOVAs indicated significant overall PA differences between weekdays and weekend days, regardless of the participant groups ($F=28.07$, $P<.01$, partial $\eta^2=.29$, observed power=0.99). Post hoc results revealed that weekday overall PA was significantly higher than weekend day PA (+92.63, 382.48 versus 289.85). Furthermore, significant group-by-day interactions were evident in both overall PA ($F=10.33$, $P<.01$, partial $\eta^2=.13$, observed power=0.89) and MVPA% ($F=4.72$, $P<.05$, partial $\eta^2=.07$, observed power=0.57), indicating inconsistent directions of between-day differences within each group.

The Figure provides further analysis according to the participant group and the day of the week for each significant PA level. With regard to weekday PA, participants with ASD were less active than participants with TD (counts per minute: $F=9.65$, $P<.01$; MVPA%: $F=4.75$, $P<.05$), and for weekend PA, they were similarly active (counts per minute: $F=0.12$, $P=.73$; MVPA%: $F=0.33$, $P=.57$). In addition, the PA differences among the days of the week within each group revealed that the overall PA of participants with ASD during weekdays was higher than that during weekend days ($F=4.58$, $P<.05$). However, the percentage of time engaging in MVPA did not differ between weekdays and weekend days in participants with ASD ($F=0.16$, $P=.69$). For the participants with TD, weekday PA was significantly higher than weekend PA (counts per minute: $F=23.74$, $P<.01$; MVPA%: $F=20.78$, $P<.01$).

Physical Fitness in Participants With and Without ASD

We observed significant differences between the 2 groups with regard to the PACER, isometric push-up, curl-up, and sit-and-reach tests (Tab. 3), indicating that participants with ASD exhibited lower levels of cardiovascular endurance, upper body and abdominal muscular strength and endurance, and lower body flexibility compared with participants with TD. No significant differences in body composition were observed between the groups.

Relationships Between PA and Physical Fitness

Table 4 shows the Pearson correlations between the parameters of PA levels (counts per minute and MVPA%) and physical fitness scores in participants with ASD and participants with TD.

Participants with ASD. A low correlation was observed between overall PA (in counts per minute) and cardiovascular endurance and upper body and abdominal muscular strength and endurance. A low correlation was observed between MVPA% and upper body muscular strength and endurance. A moderate correlation was observed between MVPA% and abdominal muscular strength and endurance. No significant correlations were observed between PA (counts per minute and MVPA%) and flexibility, nor between PA (counts per minute and MVPA%) and body composition.

Participants without ASD. Low correlations were observed between PA

Table 3.
Physical Fitness Measures of Participants[a]

Parameter	ASD Group (n=35)	TD Group (n=35)	t	P
BMI (kg/m²)	21.77±4.73	21.63±4.12	0.13	.90
20-m PACER	17.09±12.44	42.09±15.63	−7.40	.00
Isometric push-up (s)	29.00±15.54	40.00±0.00	−4.19	.00
Curl-up	12.29±19.78	25.31±22.21	−2.59	.01
Sit-and-reach (cm)				
Right leg	22.06±11.40	30.00±8.71	−3.28	.00
Left leg	21.41±10.88	29.69±8.69	−3.52	.00

[a] Data are presented as mean±SD unless otherwise specified. BMI=body mass index, PACER=Progressive Aerobic Cardiovascular Endurance Run, ASD=autism spectrum disorders, TD=typically developing.

(counts per minute and MVPA%) and cardiovascular endurance. A low correlation was observed between MVPA% and left-leg flexibility and between abdominal muscular strength and endurance. A moderate correlation was observed between MVPA% and right-leg flexibility. No significant correlations were discovered between PA (counts per minute and MVPA%) and body composition.

Physical Fitness in Participants With and Without ASD Who Did and Did Not Meet the Daily MVPA Recommendation

The results from the secondary analyses (Tab. 5) (all participants were split into 4 groups by using the nonparametric Kruskal-Wallis tests) indicated that participants with ASD who did not meet the daily MVPA recommendation scored significantly lower on all physical fitness measures except body composition compared with participants with TD who met the guideline. Participants with ASD who did not meet the guideline also scored significantly lower on cardiovascular endurance and muscular strength and endurance than did participants with ASD who met the recommendation. Participants with TD who did not meet the recommendation scored significantly higher on cardiovascular endurance and upper body muscular strength and endurance compared with participants with ASD who did not. Participants with ASD who met the guideline and participants with TD who did not meet the recommendation also scored significantly lower on cardiovascular endurance and lower body flexibility than did participants with TD who met the guideline.

Discussion

This study is one of few attempts to examine PA and physical fitness in participants with and without ASD, and the association between PA and physical fitness in each group. The PA results indicated that only 37% of participants with ASD and 60% of participants with TD met the daily 60 minutes or more of MVPA standard in the present study. These results are lower than some[14–16] but not all[13] previous studies. In addition, participants with ASD were less active overall compared with participants with TD (Tab. 2), and this finding may be partly attributable to the social model of disability,[35] in which the society fails to provide appropriate services to adequately ensure that the needs of people with ASD are fulfilled. According to the parent-report questionnaire, approximately 42% of the participants with TD were enrolled in extracurricular PA programs, but only 14% of the participants with ASD participated in those programs, and their time spent engaged in those activities was minimal (approximately 60 minutes per week). Access to

Table 4.
Correlations Between Physical Activity Across Weekend Days and Weekdays and Fitness Measures for Adolescents With and Without ASD[a]

Parameter	ASD Group (n=35)				TD Group (n=35)			
	Average Counts per Minute		MVPA%		Average Counts per Minute		MVPA%	
	r	P	r	P	r	P	r	P
BMI (kg/m²)	.05	.80	.33	.06	.08	.65	.08	.64
20-m PACER	.34*	.04	.27	.12	.45**	.00	.49**	.00
Push-up (s)	.48**	.00	.42*	.01	. . .[b]		. . .[b]	
Curl-up	.39*	.02	.59**	.00	.20	.26	.37*	.03
Sit-and-reach (cm)								
Right leg	.03	.88	.14	.41	.32	.06	.62**	.00
Left leg	−.01	.94	.12	.51	.20	.25	.39*	.02

[a] The correlation is graded as 0–.25=little, .26–.49=low, .50–.69=moderate, .70–.89=high, and .90–1=very high (Domholdt E. Statistical analysis of relationships: the basics. In: *Physical Therapy Research: Principles and Applications*. Philadelphia, PA: Saunders; 2000). BMI=body mass index, PACER=Progressive Aerobic Cardiovascular Endurance Run, MVPA%=daily average percentage of time spent in moderate-to-vigorous physical activity, ASD=autism spectrum disorders, TD=typically developing. Level of significance: * $P<.05$, ** $P<.01$.
[b] r could not be calculated because push-up is a constant variable in TD group participants (all scored 40 s).

Table 5.
Physical Fitness Measures of Participants Who Did and Did Not Meet the Daily MVPA Recommendation[a]

Parameter	ASD Group (n=35)		TD Group (n=35)		χ^2 Test	Post Hoc Test
	1. <60 min MVPA (n=22)	2. ≥60 min MVPA (n=13)	3. <60 min MVPA (n=14)	4. ≥60 min MVPA (n=21)		
BMI (kg/m²)	21.10±4.08	22.76±5.56	20.70±3.12	22.00±4.45	1.85	
20-m PACER	13.00±8.63	24.00±15.02	29.57±8.50	50.43±13.63	47.23*	1<2, 3<4
Push-up (s)	22.50±16.49	40.00±0.00	40.00±0.00	40.00±0.00	37.04*	1<2, 3, 4
Curl-up	3.50±6.55	27.15±25.54	17.43±20.27	30.57±22.34	30.08*	1<2, 4
Sit-and-reach (cm)						
Right leg	20.25±12.35	25.12±9.24	23.71±9.15	34.19±5.33	18.92*	1, 2, 3<4
Left leg	20.09±12.17	23.65±8.19	24.43±7.82	33.19±7.51	15.61*	1, 2, 3<4

[a] Data are presented as mean±SD unless otherwise specified. ASD=autism spectrum disorders, TD=typically developing, BMI=body mass index, PACER=Progressive Aerobic Cardiovascular Endurance Run, MVPA=moderate-to-vigorous physical activity. * $P<.01$.

extracurricular activities may be a factor in the occurrence of large disparities in activity options between participants with and without ASD. Youth with ASD are disadvantaged because of societal treatment, rather than the actual impairment, and the lack of societal acceptance and support may limit access to community and educational PA opportunities.[35] Other reasons underlying group differences in PA may be poor social skills,[5] a lack of motivation and enjoyment,[36] or less favorable motor skills[9] in participants with ASD because these variables may interfere with successful PA participation and affect the frequency of PA involvement in this population.

The day of the week affected the PA variables in the present study. Weekday PA was higher than weekend-day PA in both groups of participants, and the participants with ASD were less active compared with the participants with TD during weekdays. We assumed that participants with and without ASD would exhibit higher PA levels during weekdays than on the weekends because previous studies have indicated that physical education and recess time play a crucial role in the level of PA in which students engage in during schooltime.[14] Because parents of participants with and without ASD reported that their children relied on sedentary activities rather than physical activities after school,[14] we determined that physical education and recess opportunities provided at school could be factors contributing to the higher PA levels observed during weekdays in this study. However, several studies on youth with ASD have reported no differences in the PA of these youth between weekdays and weekends,[12,15] whereas others have observed that youth with ASD spent less time engaging in moderate PA than did children with TD on weekdays.[13] Therefore, these findings warrant further study.

The significant differences between the physical fitness levels of participants with and without ASD are as anticipated. All physical fitness indices, except for body composition, indicated that participants with ASD exhibited lower levels of cardiovascular endurance, upper body and abdominal muscular strength and endurance, and lower body flexibility than did participants with TD. These results are consistent with those of previous research indicating that participants with ASD exhibited lower fitness levels in cardiorespiratory endurance, muscular strength and endurance, and flexibility, compared with those participants with TD.[9,18] Furthermore, regarding the physical fitness differences, the results obtained from secondary analyses suggested that engaging in at least 60 minutes of MVPA daily may be critical for participants with ASD. These participants may be more likely to improve their physical fitness level by increasing their daily MVPA. Physical activity interventions for people with ASD have consistently produced positive outcomes when structured physical activities were provided, either in an individual or a group context.[37] Physical activity interventions should target fitness training involving ambulant support, such as explicit instruction, prompting, and consistent reinforcement, to encourage lifestyle PA and maintain proper fitness levels in daily life. Schools, health and education ministries, and governments must address the health concerns caused by inactivity among people with ASD and create and implement PA programs. Furthermore, motivating people with ASD and providing individualized training adapted for them also may be strategies for improving their overall fitness.

Findings from the present study add new evidence in the field of health-related PA and physical fitness in people with ASD. Table 4 shows that cardiovascular endurance was positively and significantly related to daily PA in participants with and without ASD. These positive relationships, albeit low and ranging from $r=.34$ to $.49$, could be interpreted as indications that participants with and without ASD exhibiting high aerobic fitness levels tend to be slightly more physically active in daily life, and the opposite suggesting that short, intermittent bouts of PA may be crucial in promoting the cardiovascular fitness of participants with and without ASD. We also observed that for participants with and without ASD, daily PA was positively and significantly related to muscular strength and endurance. High PA levels of participants with and without ASD indicated increased muscular strength and endurance during fitness performance, and vice versa. Research indicated that enhanced muscular endurance, older age, and urban schooling were factors that contributed to the variance in more favorable aerobic capacity in boys.[38] It is possible that the abundant PA equipment and space in the urban schools that were studied contributed to higher PA and more favorable aerobic capacity and muscular endurance in the participants in this study. However, this study did not collect information on the school PA resources, spaces, and settings. Future research should address these potential factors in the relationship between students' PA and physical fitness. Notably, daily PA was positively and significantly related to flexibility in participants with TD, but this finding was not observed in participants with ASD. These conflicting relationships in daily PA and flexibility between groups could be caused by diverse habitual movement patterns and PA levels between participants with and without ASD, which are crucial determinants of flexibility.[39] However, the reasons underlying these inconsistent correlations between PA levels and health-related physical fitness components in participants with and without ASD are unknown. The lack of strong relationships or no correlations between daily PA and physical fitness components in this study may have been due, in part, to a ceiling effect in physical fitness measures (eg, scoring of an isometric push-up for up to 40 seconds). This finding also may indicate that other potential factors, such as heredity and sociocultural conditions, could be more dominant factors than daily PA in determining PA and physical fitness in this population.

We observed no correlations between PA and body composition in participants with and without ASD. Previous studies have suggested that low levels of PA in youth with ASD are related to increased obesity,[12] whereas other studies have disputed this finding by suggesting no correlation[13] or even a positive correlation between PA level and obesity in youth with ASD.[16] Studies on youth with TD also have produced inconsistent findings regarding the relationship between PA and obesity.[40,41] In addition, numerous factors, including heredity, diet, maturation, nutrition, and other behavioral and environmental factors, influence the health-related physical fitness of youth. This study did not investigate these variables; therefore, further research could be directed in these areas. Nevertheless, the correlations between PA levels and physical fitness components observed in this study suggest that the relationship between habitual PA and aerobic fitness in youth should be emphasized, considering the recent evidence that youth with high levels of cardiorespiratory fitness exhibited reduced and clustered cardiometabolic risk scores.[2]

This study had several limitations. The cross-sectional design limits the generalization of the findings and precludes any firm conclusion regarding the causality of the associations between PA and physical fitness. The PA levels may have been underestimated because the accelerometer malfunctions when assessing PA during water activities, up-hill walking, and non–weight-bearing activities (eg, bicycling), although only a few participants reported a considerable duration of these activities. Similarly, the small size of the sample makes it difficult to draw a conclusion regarding the variables that differentiate participants who did and did not meet the guideline. Therefore, future studies should compare larger samples. In addition, the presence of stereotypic behaviors in participants with ASD, the maturational status of each participant, physical education content, extracurricular opportunities that each school offered, and possible ceiling effects of physical fitness measures (eg, up to 40 seconds of an isometric push-up and up to a maximum of 75 curl-ups) are areas that warrant further research. Furthermore, even though all attempts were made to obtain a homogeneous sample of students that were high functioning on the autism spectrum, differences in abilities to participate in PA were not evaluated and may have influenced the findings. Finally, although this study used an objective method of PA monitoring by using accelerometry, the device and the associated cutoff points used to define PA intensities may differ slightly compared with those used in other studies. Consequently, the controversy remains regarding which set of cutoff points should be used to establish PA intensity thresholds that are most representative of MVPA in youth.[42]

In conclusion, participants with ASD are at greater risk of being insufficiently active and physically unfit compared with the TD participants. Habitual PA and intermittent, accumulated MVPA may be critical in influencing the aerobic and muscular strength and endurance fitness levels of participants with and without ASD. Further studies are required to clarify which dimensions and types of PA are most beneficial for cardiovascular fitness and muscular strength and endurance among participants with and without ASD. Furthermore, the physical fitness level of participants with ASD who engage in less than 60 minutes of daily MVPA warrants more attention. We suggest that PA intervention strategies aimed at improving the health-related physical fitness of youth with ASD be provided on a daily, structured, and individualized basis.

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