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Original Article

Objective Physical Activity and Health-Related Fitness in Children with Autism Spectrum Disorders and Typically Developing Children: A Gender Study

Amin Gholami[1], PhD; Maryam Abdoshahi[2]*, PhD; Malihe Naeimikia[1], PhD

[1]Department of Motor Behavior, Sport Sciences Research Institute, Tehran, Iran
[2]Department of Motor Behavior, Faculty of Sport Sciences, Alzahra University, Tehran, Iran

Corresponding author:* Maryam Abdoshahi, PhD; Department of Motor Behavior, Faculty of Sport Sciences, Alzahra University, Postal code: 19938-91176, Tehran, Iran. **Tel: +98-9382351861; **Email:** m.abdoshahi@alzahra.ac.ir

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Abstract

Background: Physical activity (PA) patterns and health-related physical fitness (HRPF) among children with autism spectrum disorder (ASD), particularly with emphasis on gender differences are less examined. The present study aimed to objectively assess the PA and HRPF of children with ASD and to compare these findings with those of typically developing (TD) children, with a particular focus on gender differences.
Method: This descriptive-correlational study was done in Tehran, Iran in 2023. We selected 76 students with ASD (35 girls, Mage=13.63±2.14) and 85 TD children (40 girls, Mage=13.47±2.04) as the study sample through the convenience sampling method. PA and HRPF were assessed using an accelerometer and the Brockport Physical Fitness Test, respectively. Independent t-tests and linear regressions were used to analyze data through SPSS version 26.
Results: The ASD group engaged significantly in fewer daily moderate-to-vigorous PA (MVPA) than the TD group (39.93±13.60 vs. 46.87±11.70 minutes per day, respectively, P=0.013). Boys in both ASD and TD groups exhibited significantly higher PA and HRPF as compared with girls (P<0.001 and P=0.040, respectively). As expected, MVPA was correlated with physical fitness in ASD (r=0.298, P<0.001) and TD groups (r=0.432, P<0.001) indicating that participants with higher MVPA were more physically fit.
Conclusions: The results emphasized the need of targeted strategies and offerings geared to children and adolescents with ASD to promote an adequate level of PA and health-related physical fitness. Developing specific strategies for children with ASD is vital to promote proper PA and HRPF.

Keywords: Autism, Exercise, Physical fitness, Instrumentation, Gender

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1. Introduction

Physical activity (PA) involves any movement of the body that requires energy expenditure and is carried out by skeletal muscles (1, 2). Engaging in regular PA is correlated with various physical and mental health benefits, as well as a reduction in obesity (3-6). Additionally, PA during childhood can have a long-lasting impact on PA in adulthood (7, 8). It is suggested that adolescents partake in at least 60 minutes of moderate-to-vigorous PA (MVPA) each day of the week. It is also advised to limit sedentary behavior (SB) to an appropriate level (9).

Children diagnosed with developmental disorders tend to participate in PA less frequently than typically developing (TD) counterparts (10, 11). Autism spectrum disorder (ASD) is one of the most prevalent developmental disorders in youth, characterized by deficits in social interactions and communication abilities, along with repetitive behaviors (1, 12). Difficulties with motor skills are other features observed in ASD (1, 12-14). It is posited that youth with ASD are less inclined to participate in PA, potentially due to the aforementioned challenges as well as personal and physical obstacles (15-18). Research indicated that merely 44% of youth with ASD adhere to international guidelines (19-22). Furthermore, youth with ASD are observed to spend considerably more time each day in sedentary behavior (SB) and less time in MVPA when compared with TD counterparts (23-25). Li and colleagues discovered that youth with ASD engage in 30 minutes less of daily MVPA than their TD counterparts, falling short of the recommended guidelines (26).

Several studies have highlighted the impact of PA on health-related physical fitness (HRPF) in individuals with ASD (27-30). For instance, research has shown that youth with ASD tend to have lower MVPA and HRPF compared with their TD peers (31, 32). Additionally, studies have indicated that youth with ASD exhibit lower levels of PA and HRPF in comparison with their TD counterparts (33, 34). Furthermore, it has been demonstrated that individuals with ASD generally have significantly lower levels of PA and HRPF when compared with TD children (35). These findings suggest that there are group-dependent relationships between HRPF and PA in individuals with ASD.

Previous research has explored PA, SB, and HRPF in youth with ASD (28, 30-33). However, many of these studies have been constrained by small sample sizes, the absence of a control group, or failure to account for gender variations. Given these limitations and the potential significance of enhancing HRPF and PA in the habilitation process of individuals with ASD, it is crucial to investigate their HRPF and PA using a larger sample size while also considering gender differences. The present study aimed to analyze PA, SB, and HRPF in children with ASD and compare them with TD children. This study used a larger sample size than previous research and took gender differences into account (27, 29-31). Our hypotheses were as follows: 1) children with ASD would spend less time participating in PA compared with TD children; 2) individuals with ASD would exhibit lower HRPF than TD children; 3) there would be positive correlations between PA and HRPF; 4) there would be negative correlations between PA and body mass index (BMI); and 5) boys would demonstrate higher levels of PA and HRPF than girls.

2. Methods

This descriptive-correlational study was done in Tehran, Iran in 2023. A total of 76 students with ASD (35 girls) aged 10 to 17 years (mean=13.63±2.14) from special schools were chosen through convenience sampling method and based on correlational research (21), with $\alpha=0.05$, $\beta=0.05$, and $r=0.20$. The inclusion criteria for ASD students were: 1) being diagnosed with ASD based on previous research (36), and 2) providing written consent by parents. The exclusion criteria for these students were: 1) having any mental retardation or physical disability that made it difficult to participate in the research protocol, and 2) failure to complete the research protocol. Moreover, 85 TD students (40 girls) aged 10 to 17 years (mean=13.74±2.04) from regular schools voluntarily participated in this study. The inclusion criteria for TD children were: 1) not being diagnosed for ASD, and 2) providing written consent by parents. The exclusion criteria for these students were: 1) having any mental retardation or physical disability that made it difficult to participate in the research protocol, and 2) failure to complete the research protocol. Parents and students were provided detailed explanations of all study procedures, and parental consent was acquired in written form.

Before commencing the research protocol, the demographic questionnaire was completed by the parent or caregiver of every student. Subsequently, an informational session was conducted for each participant to provide details about the objectives and procedures of the study. Data collection occurred in a secluded, noise-free room in the school gym, where the students completed HRPF tests over two consecutive days before using the accelerometer. The measurements of height and weight were conducted in a confidential environment, where participants were attired in lightweight clothing and without footwear. A comprehensive description of the assessments is outlined below.

PA was assessed using the accelerometer, which has strong validity and reliability (37, 38). Participants were instructed to wear the accelerometer on their right hip continuously for seven days, except when showering, engaging in water-related activities, or sleeping. To ensure the participants' adherence and proper use of the accelerometer, regular contacts were maintained via WhatsApp or phone calls. Once completed, the accelerometer data were extracted, processed, and evaluated using the respective software.

HRPF was measured using the Brockport Physical Fitness Test (BPFT) (39). BPFT is a criterion-reference test to measure HRPF in youth with and without disabilities aged 10 to 17 years old. The BPFT full battery is comprised of 27 items that fall into four components musculoskeletal functioning (16 items), aerobic functioning (3 items), flexibility (5 items), and body composition (3 items). Four to six items of all four components are assumed to represent the overall individual fitness. In the present study, five items were selected to assess HRPF including two items to measure musculoskeletal functioning (i.e., isometric push-up and modified curl-up), one item to measure aerobic function (i.e., one-mile run/walk), one item for measuring flexibility (i.e., the back saver sit-and-reach), and one item to measure body composition (i.e., BMI).

The isometric push-up assessment measures maximum strength endurance in the chest and arm muscles. In this evaluation, the person was directed to hold a raised push-up stance for a maximum of 40 seconds. They positioned their hands directly under the shoulders, arms fully extended, bodies forming a straight line, and toes touching the mat. The time the individual maintained the correct position, rounded to the nearest second, was noted as their ultimate score. The highest possible score attainable was 40 seconds.

The modified curl-up assessment measures the endurance and strength of the abdominal muscles. In this evaluation, the participant lies supine with their knees flexed at approximately 140 degrees, feet flat on the ground, and hands placed on their thighs. The participant is directed to execute as many curl-ups as possible, adhering to a rhythm of one curl-up every three seconds. The individual gradually curls up, moving their fingers along the measuring strip positioned beneath their knees until their fingertips reach the opposite end, before returning to the starting position. The examiner records the total number of curl-ups for scoring purposes. The test proceeds until the participant can no longer maintain proper form or until they reach a total of 75 curl-ups.

The aerobic function of the students was evaluated using a one-mile run/walk test. To conduct the test, the student commenced running upon hearing the cue "Ready? Go!". The duration, measured in minutes and seconds, that the student took to finish the mile was documented as their score.

Flexibility was assessed in this study using the back-saver sit-and-reach test. During the test, the participants removed their shoes and stood in front of the sit-and-reach box. They sat with one leg straight and the other bent, placing the foot of the bent leg next to the knee of the straight leg. With their arms extended forward over the measuring scale and palms facing downward, one hand on top of the other, participants slowly reached forward four times, pausing on the fourth reach for measurement. The score was then recorded to the nearest centimeter based on the distance reached by the fingertips.

BMI was used to assess body composition. A qualified staff member adhered to established protocols to determine height and weight. Height was measured with a precision of 0.1 cm, and weight was measured with a precision of 0.1 kg. Following this, BMI was computed using the standard formula: weight (kg) divided by height (m^2).

Using SPSS version 26, mean and standard deviation (SD) were computed to describe the data. Independent t-tests were performed to examine differences in PA and HRPF between students with and without ASD, as well as to identify gender disparities in PA and HRPF. Furthermore, linear regressions were carried out to establish the correlation between PA and HRPF, with HRPF serving as the dependent variable. Subsequently, the sample was divided into three groups based on the amount of daily MVPA. Participants with over 60 minutes, between 30 to 60 minutes, and less than 30 minutes of daily MVPA were categorized as high, moderate, and low daily MVPA groups, respectively. One-way analysis of variance (ANOVA) with the Tukey HSD test was then employed to compare HRPF status among these groups. A p value of 5% or lower was considered to be statistically significant.

3. Results

Demographic characteristics of the study participants showed similar results in ASD and TD groups: mean age of 13.63±2.14 vs. 13.74±2.04 in ASD and TD children, respectively; height of 160.86±10.08 vs. 161.22±7.04 in ASD and TD children, respectively, and weight of 51.33±8.09 vs. 51.45±7.07 in ASD and TD, respectively. The majority of students attended the first secondary high school. Additionally, a large number of parents had a stable financial status and had obtained a college degree. Finally, the majority of students rose between 6:00 and 7:00 A.M. and slept between 10:00 and 11:00 P.M.

According to Table 1, there were no significant gender differences concerning SB (74.39% and 75.70%, respectively, P=0.190), light PA (LPA) (17.86% and 18.08%, respectively, P=0.652), and overall MVPA duration (7.76% and 6.22%, respectively, P=0.055).

Table 1: Comparison of physical activity pattern among boys and girls

Variables	Groups		Mean	SD	Gender Comparison	Comparison of ASD and TDC
Sedentary Behavior%	ASD	B (n=41)	74.39	2.49	t=-1.336 P=0.190	t=8.116 P<0.001
		G (n=35)	75.70	3.39		
		All (n=76)	74.93	2.93		
	TDC	B (n=45)	67.99	4.53	t=-0.736 P=0.435	
		G (n=40)	68.86	3.71		
		All (n=85)	68.40	4.15		
Light PA%	ASD	B (n=41)	17.86	1.16	t=-0.455 P=0.652	t=-10.081 P<0.001
		G (n=35)	18.08	1.82		
		All (n=76)	17.95	1.45		
	TDC	B (n=45)	22.20	2.32	t=-1.006 P=0.319	
		G (n=40)	22.89	2.54		
		All (n=85)	22.52	2.42		
MVPA%	ASD	B (n=41)	7.76	1.96	t=1.983 P=0.055	t=-3.355 P=0.001
		G (n=35)	6.22	2.69		
		All (n=76)	7.12	2.38		
	TDC	B (n=45)	9.80	3.31	t=1.973 P=0.054	
		G (n=40)	8.26	2.04		
		All (n=85)	9.08	2.87		
Daily MVPA (min)	ASD	B (n=41)	43.92	10.47	t=2.197 P=0.035	t=-2.548 P=0.013
		G (n=35)	34.33	15.75		
		All (n=76)	39.93	13.60		
	TDC	B (n=45)	50.96	11.46	t=2.820 P=0.007	
		G (n=40)	42.28	10.37		
		All (n=85)	46.87	11.70		

* B=Boys; G=Girls; ASD: Autism spectrum disorder; TDC: Typically developing children; MVPA: Moderate-to-vigorous physical activity

Only 16.7% of students with ASD adhered to the recommended activity levels. Notably, boys exhibited a significantly higher daily MVPA participation compared with girls (43.92 vs. 34.33 minutes, respectively, P=0.035).

There were no significant gender differences observed concerning SB (67.99% and 68.86%, respectively, P=0.435), light PA (LPA) (22.20% and 22.89%, respectively, P=0.319), and total time of MVPA (9.80% and 8.26%, respectively, P=0.054) in the TD group. Only 15.7% of the TD group fulfilled the guidelines. Boys engaged significantly more in daily MVPA than girls (50.96 vs. 42.28 minutes, respectively, P=0.007). Additionally, the ASD group spent significantly more time in SB than the TD group (P<0.001), while the TD group spent significantly more time in LPA (P<0.001), MVPA (P=0.001), and daily MVPA (P=0.013) compared with the ASD group.

Concerning HRPF (Table 2), the findings indicated that boys in the ASD group exhibited significantly superior performance in isometric push-ups (P=0.021), modified curl-up (P=0.040), and one-mile run/walk (P=0.037) in comparison with girls. Conversely, there were no significant gender differences in BMI (P=0.773) and sit-and-reach (P=0.155). In terms of the TD group, the results revealed that boys displayed significantly better performance in modified curl-up (P=0.022) and one-mile run/walk (P=0.012) than girls, while no significant gender difference was observed in BMI (P=0.301), isometric push-up (P=0.435), and sit-and-reach (P=0.132). Additionally, the TD group exhibited significantly superior performance in all HRPF components (P<0.001), except BMI (P=0.485), when compared with the ASD group.

Results of linear regression for ASD and TD are presented in Tables 3 and 4, respectively. For the ASD group, age was directly correlated with BMI (P=0.001), but not with other HRPF components. Gender was inversely correlated with isometric push-ups (P=0.019) and modified curl-ups (P=0.034) and directly correlated with one-mile run/walk (P=0.017). SB was inversely correlated with isometric push-ups (P<0.001), modified curl-ups (P<0.001), and sit-and-reach (P=0.006), and directly correlated with BMI (P=0.007) and one-mile run/walk (P<0.001). LPA was not significantly correlated with none of the HRPF components.

Table 2: Comparison of physical fitness among boys and girls of ASD and TDC groups

Variables	Groups		Mean	SD	Gender Comparison	Comparison of ASD and TDC
BMI (kg/m^2)	ASD	B (n=41)	19.65	1.54	t=-0.291 P=0.773	t=0.701 P=0.485
		G (n=35)	19.79	1.09		
		All (n=76)	19.71	1.36		
	TDC	B (n=45)	19.41	1.02	t=-1.045 P=0.301	
		G (n=40)	19.68	0.76		
		All (n=85)	19.54	0.91		
Isometric Push-up (second)	ASD	B (n=41)	30.90	5.74	t=2.429 P=0.021	t=-10.667 P<0.001
		G (n=35)	25.40	7.87		
		All (n=76)	28.61	7.15		
	TDC	B (n=45)	39.66	1.10	t=0.786 P=0.435	
		G (n=40)	39.37	1.52		
		All (n=85)	39.52	1.31		
Curl-up (number)	ASD	B (n=41)	16.90	5.65	t=2.132 P=0.040	t=-6.660 P<0.001
		G (n=35)	12.60	6.40		
		All (n=76)	15.11	6.26		
	TDC	B (n=45)	27.22	7.40	t=2.362 P=0.022	
		G (n=40)	22.62	6.37		
		All (n=85)	25.05	7.24		
One-Mile Run (second)	ASD	B (n=41)	12.36	2.25	t=-2.171 P=0.037	t=4.959 P<0.001
		G (n=35)	14.17	2.74		
		All (n=76)	13.11	2.59		
	TDC	B (n=45)	10.18	1.51	t=-2.620 P=0.012	
		G (n=40)	11.44	1.91		
		All (n=85)	10.77	1.81		
Sit-and-Reach	ASD	B (n=41)	21.52	4.49	t=-1.454 P=0.155	t=-6.608 P<0.001
		G (n=35)	23.52	3.39		
		All (n=76)	22.35	4.14		
	TDC	B (n=45)	28.51	5.52	t=-1.531 P=0.132	
		G (n=40)	30.89	5.56		
		All (n=85)	29.63	5.61		

*B=Boys; G=Girls; ASD: Autism spectrum disorder; TDC: Typically developing children; SD: Standard deviation; BMI: Body mass index

Table 3: Prediction of physical fitness components (including BMI, push-up, curl-up, one mile run, and sit and reach) by age, gender, and physical activity pattern in ASD Group

Variables	Index	BMI	Push-up	Curl-up	One-Mile Run	Sit-and-Reach
Age	β	0.476	-0.022	-0.071	-0.080	-0.146
	R^2	0.227	0.001	0.005	0.006	0.021
	P	0.001	0.968	0.875	0.851	0.527
Gender	β	0.050	-0.385	-0.343	0.349	0.242
	R^2	0.002	0.148	0.118	0.122	0.059
	P	0.864	0.036	0.038	0.027	0.637
Sedentary Behavior%	β	0.447	-0.734	-0.613	0.698	-0.351
	R^2	0.199	0.538	0.376	0.488	0.123
	P	0.001	<0.001	<0.001	<0.001	0.034
Light PA%	β	-0.051	0.001	0.010	0.029	0.021
	R^2	0.003	0.001	0.001	0.001	0.001
	P	0.847	0.867	0.869	0.874	0.829
MVPA%	β	-0.580	0.901	0.747	-0.875	0.419
	R^2	0.336	0.812	0.558	0.766	0.175
	P	<0.001	<0.001	<0.001	<0.001	0.036
Daily MVPA	β	-0.590	0.919	0.775	-0.891	0.432
	R^2	0.349	0.845	0.601	0.794	0.186
	P	<0.001	<0.001	<0.001	<0.001	0.001

* ASD: BMI: Body mass index; Autism spectrum disorder; PA: Physical activity; MVPA: Moderate-to-vigorous physical activity

Table 4: Prediction of physical fitness components (including BMI, push-up, curl-up, one mile run, and sit and reach) by age, gender, and physical activity pattern in TDC group

Variables	Index	BMI	Push-up	Curl-up	One-Mile Run	Sit-and-Reach
Age	β	0.388	0.073	-0.155	0.030	-0.056
	R^2	0.151	0.005	0.024	0.001	0.003
	P	0.001	0.746	0.736	0.716	0.758
Gender	β	0.148	-0.112	-0.320	0.350	0.214
	R^2	0.022	0.012	0.102	0.123	0.046
	P	0.859	0.891	0.047	0.043	0.746
Sedentary Behavior%	β	0.351	0.195	-0.100	0.373	-0.335
	R^2	0.123	0.038	0.010	0.139	0.113
	P	0.038	0.724	0.936	0.001	0.029
Light PA%	β	-0.024	-0.283	-0.170	0.044	0.097
	R^2	0.001	0.080	0.029	0.002	0.010
	P	0.958	0.041	0.584	0.749	0.869
MVPA%	β	-0.486	-0.042	0.288	-0.576	0.402
	R^2	0.237	0.002	0.083	0.332	0.162
	P	<0.001	0.239	0.025	<0.001	0.001
Daily MVPA	β	-0.420	0.115	0.454	-0.595	0.298
	R^2	0.177	0.013	0.206	0.355	0.089
	P	0.001	0.598	0.001	<0.001	0.031

* BMI: Body mass index; TDC: Typically developing children; PA: Physical activity; MVPA: Moderate-to-vigorous physical activity

MVPA was inversely correlated with BMI (P<0.001) and one-mile run/walk (P<0.001), while it was directly correlated with isometric push-up (P<0.001), modified curl-up (P<0.001), and sit-and-reach (P=0.005). Finally, daily MVPA was inversely correlated with BMI (P<0.001) and one-mile run/walk (P<0.001), while it was directly correlated with isometric push-up (P<0.001), modified curl-up (P<0.001), and sit-and-reach (P=0.001). These findings indicated that participants with lower SB and higher MVPA were more physically fit. In the TD group, age was directly correlated with BMI (P=0.001), but not with other HRPF components. Gender was inversely correlated with modified curl-up and directly correlated with one-mile run/walk (P=0.042). SB was inversely correlated with sit-and-reach (P=0.038), and directly correlated with BMI (P=0.013) and one-mile run/walk (P=0.033). LPA was inversely correlated with isometric push-up (P=0.029), and not with other HRPF components. MVPA was inversely correlated with BMI (P<0.001) and one-mile run/walk (P<0.01), while it was directly correlated with isometric modified curl-up (P<0.001), and sit-and-reach (P=0.040). Finally, daily MVPA was inversely correlated with BMI (P=0.041) and one-mile run/walk (P<0.001), while it was directly correlated with modified curl-up (P=0.001), and sit-and-reach (P=0.25). These findings indicated that participants with lower SB and higher MVPA were more physically fit.

The data presented in Figure 1 illustrates the average HRPF components of ASD and TD groups across various levels of daily MVPA. In the ASD group, 16.7%, 30.6%, and 52.8% of the participants were categorized into high, moderate, and low MVPA groups, respectively. The results of ANOVA indicated that individuals with high MVPA had significantly lower BMI, higher isometric push-ups, modified curl-ups, higher sit-and-reach scores, and faster one-mile run performance as compared with those with moderate or low MVPA. Additionally, students with moderate MVPA showed better performances in isometric push-ups and one-mile run-walk as compared with low-MVPA students. These findings demonstrated that higher MVPA is associated with better HRPF. In the TD group, 15.7%, 72.5%, and 11.8% of the participants were allocated to high, moderate, and low MVPA groups, respectively. The ANOVA results revealed that students with high MVPA had significantly lower BMI than those with moderate MVPA, higher modified curl-up scores compared with those with low MVPA, faster one-mile run performance than those with moderate and low MVPA, and higher sit-and-reach scores than those with moderate MVPA. Similarly, students with moderate MVPA had better performances in one-mile run-walk as compared to those low-MVPA students. These findings highlighted the positive association between higher MVPA and HRPF.

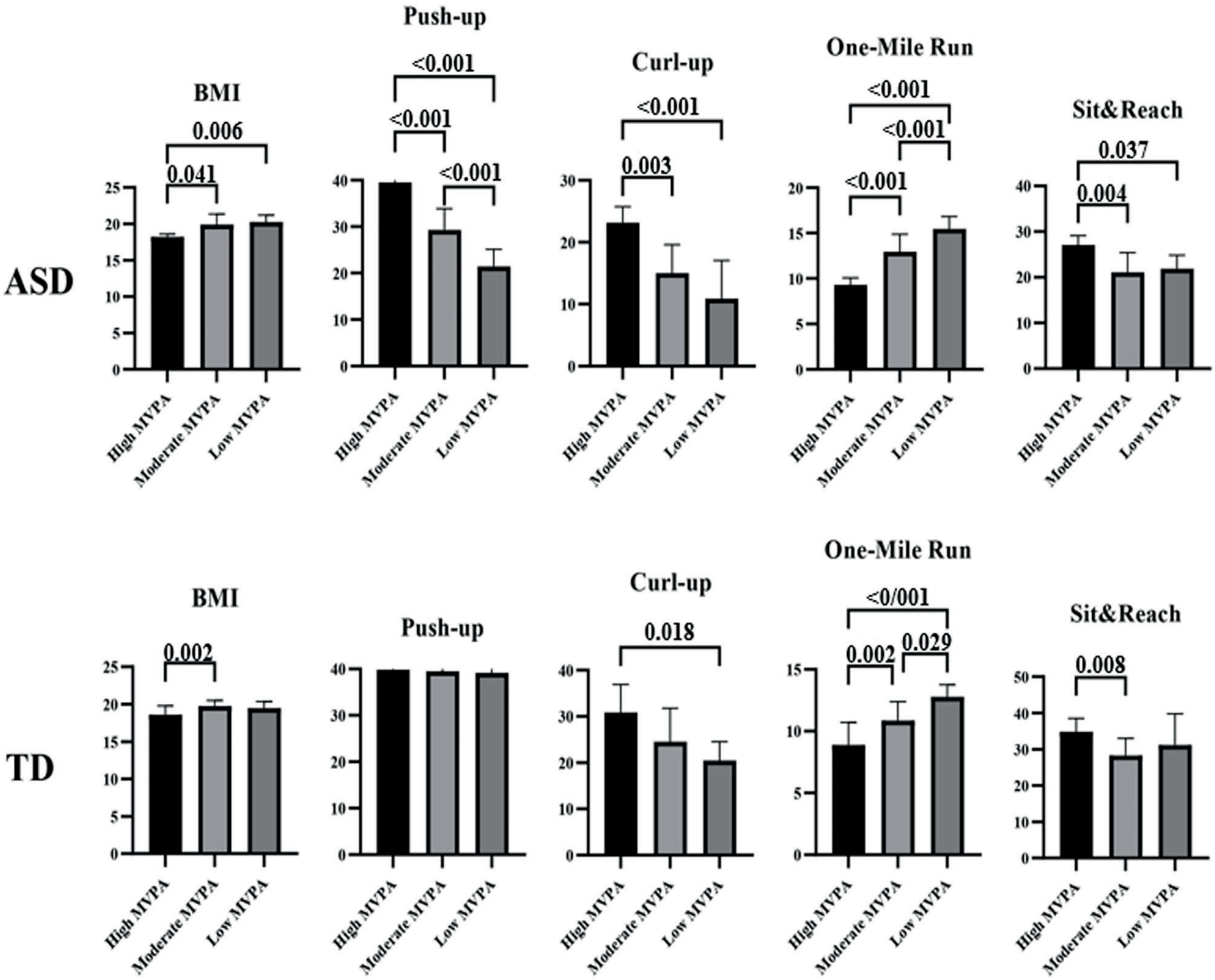

Figure 1: The figure shows the means of physical fitness scores of ASD (at top) and TD (at bottom) groups across different daily moderate-to-vigorous physical activity. * ASD: Autism spectrum disorder; TD: Typically developing children; BMI: Body mass index

4. Discussion

This study investigated PA patterns and HRPF in ASD and TD children with an emphasis on gender differences. Concerning PA pattern, our findings revealed that ASD engaged significantly in fewer amounts of MVPA per day in comparison with TD (i.e., 39.93 minutes versus 46.87 minutes, respectively). Moreover, the ASD group spent significantly more time in SB as compared with TD (i.e., 74.93% versus 68.40%, respectively). In comparison with previous studies (15-19), our ASD sample relatively engaged in lower MVPA per day. However, almost similar results were observed in some studies (10, 11). Additionally, the results of this study confirmed the initial hypothesis and are consistent with previous research findings (15-19), indicating that individuals with ASD engage in fewer MVPA per day in comparison with TD. The explanation for lower MVPA in ASD than in TD is not well understood; however, ASD may experience challenges in social interaction, motor skills, and navigating physical obstacles (26).

Given the PA pattern, our findings revealed no significant gender differences regarding SB, LPA, and MVPA in ASD. Moreover, the participants did not meet the WHO guidelines. Boys engaged significantly more in MVPA. In addition, we found an almost similar PA pattern for TD, where no significant gender differences were found in SB, LPA, and MVPA. Moreover, the participants did not meet the WHO guidelines. In this context, male participants exhibited a notably higher level of MVPA compared with their female counterparts. These findings indicated that boys of both ASD and TD were more physically active than girls. These findings confirmed our hypothesis and were in line with previous studies on TD individuals (23, 29, 35, 40).

It should be noted that this is one of the first studies to report gender differences in PA of ASD using accelerometers.

The study results suggested that efforts to encourage increased PA among youth with and without ASD should prioritize PA for girls. Research demonstrated that in TD, lower levels of MVPA in girls compared with boys can be attributed to limited opportunities for PA in school, lack of parental support, decreased involvement in organized sports, and gender-specific socialization related to PA (23, 25, 40).

Concerning HRPF, results indicated that the ASD group demonstrated significantly lower musculoskeletal functioning, aerobic function, and flexibility than the TD group. However, ASD and TD did not significantly differ in BMI. Limited research has been conducted comparing the HRPF of ASD to that of healthy individuals; nevertheless, the results of the study aligned with the results of earlier investigations (27-30) and supported our hypothesis, indicating that ASD has significantly lower HRPF than TD. The mechanisms underlying lower HRPF of ASD compared with TD are not well understood; however, it may be related to deficits in motor abilities and reduced opportunities for engaging sufficiently in PA (31-33). Therefore, low HRPF of youth with ASD requires special attention and immediate interventions to improve their PA and adopt an active lifestyle. Motivating and increasing the enjoyment of physical education in ASD can be considered as strategies to increase PA and consequently HRPF. Physical education instructors can enhance overall PA and HRPF among ASD by implementing techniques like fellow mentors, and peer education, incorporating enjoyable PAs into the curriculum, and addressing fundamental psychological needs in the classroom (34, 35).

Regarding gender differences in HRPF, our study indicated that boys with ASD exhibited significantly superior performance in both musculoskeletal and aerobic functions as compared with girls. However, no significant gender difference was observed in terms of flexibility and BMI. Similar patterns were identified in the TD group. These findings suggested that boys generally possess greater HRPF than girls. This aligned with previous research on TD. Notably, this study represented the first documented examination of gender differences in HRPF among individuals with ASD. Such differences can be reasonably attributed to variations in PA habits and physiological traits between male and female individuals. Consequently, these results underscore the necessity for interventions aimed at improving HRPF in both ASD and TD populations to place particular emphasis on girls.

Two important findings in this study revealed that PA plays a crucial role in enhancing HRPF in both individuals with and without ASD. The first finding involved comparing HRPF in participants engaging in low, moderate, and high MVPA. Interestingly, the results indicated that individuals with high daily MVPA had significantly higher HRPF levels as compared with those with moderate or low daily MVPA. The second finding showed a positive correlation between MVPA and HRPF, while SB was negatively correlated with HRPF. These results aligned with previous studies (3, 6, 12, 16) and suggested that participation in PA can be a key factor in improving HRPF among young people and potentially other age groups.

In addition, this study had several strengths. Firstly, we used modern accelerometers to accurately assess PA and SB, thereby avoiding common biases found in self-reporting methods. Secondly, we were able to analyze gender differences by measuring PA and HRPF in both male and female individuals.

4.1. Limitations

This study also had certain limitations. For instance, we failed to incorporate variables that could be significant in the correlation between PA and HRPF, such as the family's socio-economic status, the local environment, and individual factors. Future research should take into account these variables to gain a deeper understanding of how PA among youth with and without ASD is influenced by their individual and socio-economic surroundings.

5. Conclusions

This study was among the first studies to assess gender differences in PA and HRPF among children with and without ASD. The results suggested that PA and HRPF have been and continue to be significant concerns for individuals with ASD, particularly girls. Interestingly, our results demonstrated that individuals engaging in higher levels of MVPA exhibit superior HRPF compared with their fewer active counterparts. HRPF serves as a factor that enhances HRPF. These findings underscored the importance of implementing strategies to encourage PA among both ASD and non-ASD youth, with a specific focus on promoting PA for girls.

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Authors' Contribution

Amin Gholami: Substantial contributions to the conception, design of the work, acquisition of data for work, and drafting of work. Maryam Abdoshahi: Substantial contributions to the conception, design of the work, acquisition of data for the work, design of the work, drafting of work, and reviewing it critically for important intellectual content. Malihe Naiemikia: Substantial contributions to the conception, reviewing the work critically for important intellectual content. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work, such as the questions related to the accuracy or integrity of any part of the work.

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Ethical Approval

The research was approved by the Ethics Committee of Alzahra University, Tehran, Iran with the code of IR.SSRI.REC.1401.1717. All participants willingly took part in the study, and written consent was obtained from both students and their parents.

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