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Effects of a school-based integrative neuromuscular training exercise intervention on physical fitness among children with autism spectrum disorder

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Abstract: The purpose of this study was to examine the effect of an eight-week, school-based integrative neuromuscular training (INT) intervention on the fitness levels of seventy-eight, 4-12-year-old children with mild, moderate, or severe symptoms of autism spectrum disorder (ASD). Children participated in an INT intervention, consisting of three, one-hour sessions per week. Physical fitness was assessed pre-and post-intervention using a modified Eurofit test battery and analysed using a 3x2 ANOVA. This INT intervention resulted in significant improvements of physical fitness ($p < .05$) pre- to post-intervention (20 m sprint [$p = .044$], standing broad jump, sit and reach, handgrip and stork balance [$p < .001$]). Notably, children with severe symptoms of ASD showed significant improvements in standing broad jump ($p = .001$ [mild vs severe], $p = .012$ [moderate vs severe]), sit and reach flexibility ($p = .002$ [mild vs severe], $p = .042$ [moderate vs severe]), and handgrip strength ($p = .001$ [mild vs severe], $p = .004$ [moderate vs severe]) tests in comparison to children with mild and moderate symptoms of ASD. The results of this study support the implementation of a school-based INT intervention to reduce physical fitness disparities, while future studies should employ experimental research designs.

Keywords: Eurofit; ASD; reliability; severity; integration

Introduction

Children with autism spectrum disorder (ASD) have lower levels of physical fitness compared to children with typical development (TD) (Healy et al., 2020; Jansiewicz et al., 2006; Minshew et al., 2004; Pace & Bricout, 2015; Page & Boucher, 1998). For example, Pan (2014) demonstrated children 10-17 years with ASD had significantly lower scores (21.4 – 82.4% difference) in the Brockport physical fitness tests for motor control, coordination, balance, strength, speed, and flexibility, as compared to TD youth. Similarly, adolescents with Asperger syndrome (AS) have been shown to perform significantly worse on all measures in the Eurofit physical fitness test than their TD peers, including balance, coordination, flexibility, muscular strength, running speed, and cardiorespiratory endurance (Borremans et al., 2010). Moreover, children with ASD are almost twice as likely to be obese compared to TD children (Zheng et al., 2017). Lower fitness levels in youth may result in an increased risk of noncommunicable diseases, such as type 2 diabetes and cardiovascular diseases later in life (Sacheck & Hall 2015). Additionally, lower fitness has also been associated with decreased mental health, such as anxiety and depression

(Andermo et al., 2020; Schuch et al., 2016). To offset the physical fitness disparities experienced by children with ASD, researchers have examined the effects of a variety of exercise interventions to increase physical fitness among this population. Common intervention modalities have included aquatics (Fragala-Pinkham et al., 2011; Pan, 2011; Yilmaz et al., 2004), dance (Arzoglou et al., 2013), balance-training (Cheldavi et al., 2014), trampolining (Lourenço et al., 2015), walking (Pitetti et al., 2007), and horse riding (Wuang et al., 2010).

Aquatic-based interventions have been the most popular modality examined for the improvement of fitness among children with ASD (Fragala-Pinkham et al., 2011; Pan, 2011; Yilmaz et al., 2004). Fragala-Pinkham et al. (2011) and Pan (2011) reported significant improvements in physical fitness (cardiorespiratory endurance, local muscular endurance, and muscular strength) with the implementation of aquatic-based interventions among children aged 6-12 years with ASD. Similarly, a case study demonstrated that a 9-year-old boy with ASD achieved meaningful improvements in balance, speed, power, agility, endurance, flexibility, and upper and lower body strength following participation in a 10-week aquatic intervention (Yilmaz et al., 2004). Although beneficial for physical fitness, aquatic interventions may not be accessible for all families of children with ASD due to their reliance on swimming facilities and instructors. The cost of swimming facilities may also be a barrier to parents/guardians, schools, or communities when introducing exercise intervention modalities to children with ASD.

Community-based exercise interventions aimed at improving the physical fitness of children with ASD have also been investigated. Pitetti and colleagues (2007) reported that a nine-month treadmill walking intervention significantly reduced body mass index (BMI) (8.9% decrease) among five adolescents aged 14-19 years with severe ASD. Furthermore, Cheldavi and colleagues. (2014) investigated the effects of a six-week balance exercise intervention on children 7-10 years with ASD and reported significant improvements in their balance and postural control. Albeit effective, community-based fitness interventions may face barriers related to accessibility; they are dependent on the presence of facilities and qualified professionals within the community. Moreover, the recruitment and retention of children, cost to parents or guardians, and funding within the community may be challenging to implement effective exercise interventions.

Schools may be the optimal setting for the implementation of sustainable and scalable physical fitness interventions for children with ASD. Schools provide an opportunity to recruit a large and diverse sample of children with ASD and schools frequently have the facilities (e.g., gymnasiums) and personnel (e.g., physical education teachers) for the implementation of physical fitness programs. Although scarce, researchers have begun to examine the effect of school-based physical fitness interventions for children with ASD. Lourenço and colleagues (2015) evaluated a 20-week school-based trampoline training intervention for children aged 4-10 years with ASD, noting a significant improvement in balance, speed, coordination, and strength among the participants with ASD. Similarly, Wuang and colleagues (2010) investigated the effects of a 20-week school-based horse-riding exercise intervention, demonstrating significant improvements in the children's motor proficiency. To date school-based exercise interventions have demonstrated effectiveness for children with ASD, however, thus far they have focused on specialized sporting activities that may also be expensive to implement (e.g., horse riding and trampolining), and thus the scalability of these interventions is limited. Interventions for schools must be cost-effective and easily conducted to minimize extra planning and the need for further staffing posts for schools.

The above-mentioned studies have shown that the physical fitness of youth with ASD can be improved by participating regularly in structured exercise interventions. However, the existing literature has been limited by small sample sizes (e.g., less than 20 participants), thus often reducing the statistical power of studies and the generalizability of the findings. Small samples also limit researchers' ability to determine the influence of ASD severity (i.e., mild, moderate, severe) on the training responsiveness of children with ASD. Moreover, research is largely limited to specific modes of exercise, often dependent on facilities and equipment that may not be available in most schools or communities. In terms of long-term athlete development (LTAD), maturation level may be considered rather than chronological age (Balyi et al. 2013); thus, the exercise progression (e.g., throwing a weighted ball through a target) may be reached earlier in an exercise program for a child with mild symptoms of ASD compared to a child with severe symptoms of ASD.

Multifaceted exercise interventions such as integrative neuromuscular training (INT) have been found to result in significant improvements in health- and skill-related fitness and are cost and time-effective methods for introducing exercise to TD children (Faigenbaum et al., 2011; Myer et al., 2011). INT exercises are designed to improve neuromuscular function, muscular strength, and muscular capacity specific to sport-like activities (Myer et al., 2011), and can elicit significantly greater gains in fitness measures when compared to traditional physical education (Faigenbaum et al., 2011). An INT exercise intervention was chosen because this type of exercise has been found to develop the skills and strength necessary to increase participation in exercise and sport activities in youth (Barnett et al.. 2009; Faigenbaum et al., 2011). Positive improvements have been found when using INT with the TD population (Duncan et al., 2018) but have yet to be comprehensively studied in the ASD population. MacDonald and colleagues (2014) suggested INT exercise could address gross motor performance deficits in ASD. As INT is a multifaceted exercise intervention, it may be favourable to elicit improvements in physical fitness in heterogeneous groups of children with ASD. Multifaceted exercise interventions such as INT may be an option to improve fitness levels for children with mild to severe symptoms of ASD, while also being cost-effective and fit for school purpose. Children should alternate between low and high intensity INT exercises which is consistent with how children move and play (Faigenbaum et al., 2011). Initially, the volume of repetitions should be low to allow each child to learn how to perform each exercise correctly before progressing to the next level (Myer et al., 2011). Therefore, the current study aimed to investigate the effects of a structured school-based INT exercise intervention on fitness levels of children with ASD and examine whether responsiveness was mediated by the severity of ASD.

Materials and Methods

Participants were recruited from ASD units within seven Irish elementary schools with a total of 14 ASD units included in the study. In a single school term two schools simultaneously took part in the eight-week INT exercise intervention in their activity hall following the same program (Coffey et al., 2021). Data collection began in January 2018 and ended in March 2019. An ASD unit is an educational setting attached to a mainstream school, specifically designed to cater to the needs of six elementary students with ASD. This learning environment is suited to children with ASD as there are special needs assistants (SNAs) in the unit to assist the teachers in coordinating class. Letters were distributed to parents/guardians of children who attend ASD units describing the purposes and protocols of the study. Parents or guardians were invited to contact a member of the research team if their child was interested in participating in the study. Inclusion criteria for the study included: (a) currently a student within an ASD unit within an Irish elementary school; (b) aged 4-12 years, (c) have a formal diagnosis of ASD. Prior to the study commencing, parental/guardian permission, participant assent, and physical activity readiness questionnaires were completed for all children involved. Ethical approval was granted by the South East Technological University's research ethics committee (Number: 249/3).

Seventy-eight children (64 boys, 14 girls) with ASD enrolled in the study, representing seven schools (see Figure 1.). Participants' ages ranged from 4-12 years (mean = 7.64 years, SD = 2.03 years). Based on a teacher reported assessment of ASD symptom severity using the Gilliam Autism Rating Scale (GARS) 2nd Edition (Gilliam, 2006), the sample included participants with mild (n = 22), moderate (n = 23), and severe (n = 33) symptoms of ASD. Each unit teacher completed the GARS questionnaire prior to beginning the INT exercise intervention whereby children were categorised by ASD symptom severity (Elbahaaey et al. 2016). Participants were required to complete a minimum of 85% of the exercise sessions, and fitness measures to be included in the final analyses.

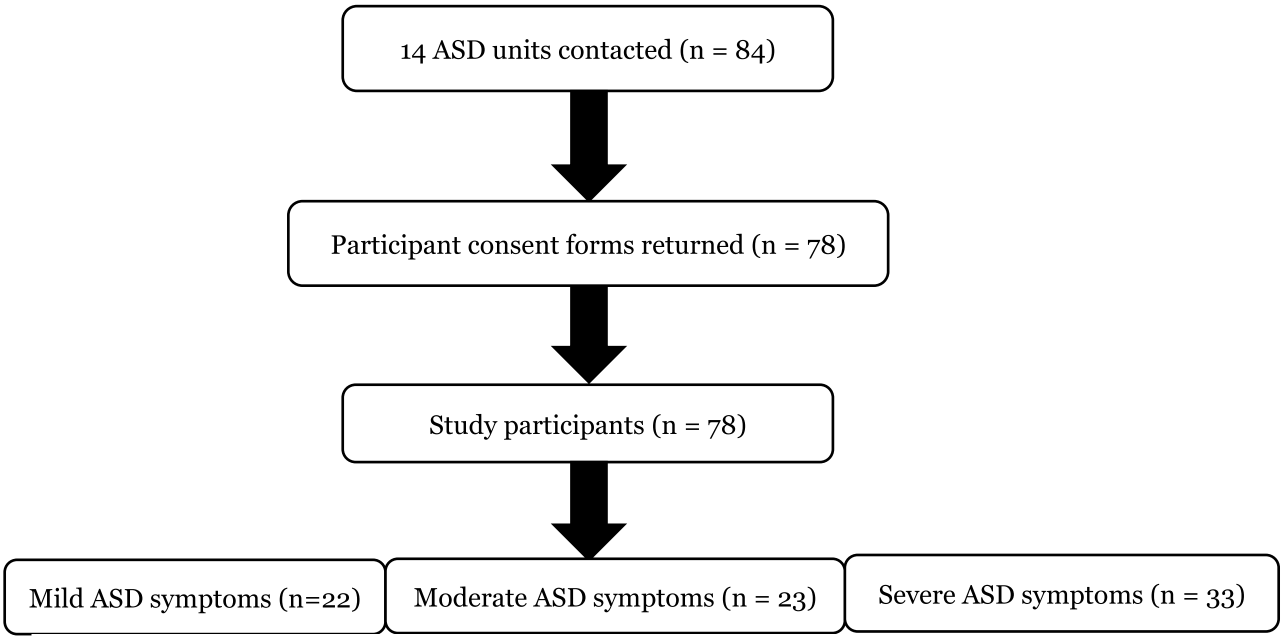

Figure 1. Participant study flow.

Procedures

A single-group, repeated measures design was employed to assess changes in participants' physical fitness because of participating in the eight-week INT exercise intervention. Physical fitness measures were collected three days prior to and three days after the intervention period. All assessments were conducted by the same principal investigator who had experience testing youth with ASD, using the same testing procedures in each school, with all tests being performed indoors.

Measurements

Autism Severity

ASD symptom severity was assessed using the GARS from teacher reported questionnaires prior to the children beginning the exercise intervention, children were categorized into three severity levels: mild, moderate, and severe (Elbahaaey et al. 2016). Research has shown that the GARS can be used for children with ASD aged 3 years and older, with parents/guardians and/or teachers completing the questionnaire to assess ASD severity (Lecavalier, 2005). Diken et al. (2012) reviewed the reliability of the GARS involving 1191 children and young adults with ASD and reported excellent test-retest reliability (r = .98-.99).

Body Mass Index

Height (cm) was measured using a stadiometer [SECA 206, Chino, USA], and weight (kg) using a calibrated electronic flat scale [SECA 807, Chino, USA]. Data were then used to calculate BMI (kg/m2) using standard methods (Davies, 1997).

Physical Fitness

A modified version of the Eurofit test battery was used to assess the physical fitness of participants, with adaptations to the sprint and balance tests and a reduction in the number of test items completed from nine to five (Council of Europe: Eurofit, 1993). The reduction in test items was to omit multiple staged tasks and prolonged tests that children with ASD may be unable to complete due to attention deficits. The modified test battery included: 20 m sprint, standing broad jump, sit and reach flexibility, handgrip strength, and the stork balance test. The Eurofit test battery has been shown to be reliable [ICCs .85 – .99] for adolescent males with an intellectual disability (MacDonncha et al., 1999). In one of the few studies to review reliability in females, Tsigilis and colleagues (2002) reported reliable measures ($R \geq .57$) for undergraduate females. There is a need to establish the test-retest reliability of the modified Eurofit test battery in elementary children with ASD, thus a subgroup of seventeen participants (13 boys, 4 girls), 4-12 years (mean = 7.88 years, SD = 1.87 years) were assessed using the modified Eurofit battery over two non-consecutive days, 48 hrs apart. Children were given one practice trial and three attempts, with their best attempt in each test used for analysis. Children wore sport shoes in each of the trials.

20 m sprint test

The 20 m sprint was recorded in seconds (s) using the Witty Timing Gates System (Microgate Witty Wireless Training Timer, Bolzano, Italy). Participants started from a standing stationary position with both feet behind (5 cm) the starting line. Timing gates were set up at the start (0 m) and the finish line (20 m), with all children encouraged to run at maximum speed past the finish line and into a designated run-off area.

Standing broad jump test

A custom-designed standing broad jump mat was marked with a measuring tape. Participants were asked to jump as far as possible, landing on two feet on the soft mat, with the distance from the rearmost foot at landing to the start line recorded as the distance jumped (cm). Children started in a standing position with two feet together and behind the start line.

Sit and reach flexibility test

The sit and reach test used a “Sit and Reach Flexibility box” (Baseline Sit-and-Reach Flexibility Box, Fabrication Enterprises, 1500 White Plains, NY, USA). Children were seated on the floor with their feet against the box assuming an upright sitting position. Children were instructed to lean forward and push their hands forward on the box until they could not go any further without their knees lifting off the ground holding the position for two seconds. The distance (cm) was recorded as to the furthest point reached on the measuring scale.

Handgrip strength test

The handgrip strength test assessed isometric strength (psi) in the dominant hand using a bulb dynamometer (Baseline squeeze (bulb) dynamometer, Fabrication Enterprises, 1500 White Plains, NY, USA), with the elbow flexed to 90° and tucked into their side while standing.

Stork balance test

Children were instructed to stand on their dominant foot, positioning their non-dominant foot against the inside knee of the supporting leg, while holding their balance for as long as possible with their best time recorded (s) using a handheld stopwatch (TIS Pro 018 Stopwatch). Children stood with their eyes open on a stable surface, to minimize movement children were required to stand on a line (5 cm wide), which was placed in the centre of the hall by the instructor, and any movement off this line resulted in the conclusion of the test.

Intervention

The eight-week INT exercise intervention involved children partaking in three, one hour sessions per week (typically Monday, Wednesday, and Friday). The INT exercise intervention replaced PE sessions in schools for the duration of the eight-week intervention. Two SNAs and the classroom teacher were present during each exercise class to support the children if needed. The exercise intervention comprised of game-based exercises using INT (Faigenbaum et al., 2014). These exercises were achieved through activities designed to motivate the children. The intervention was adapted to meet each child's specific needs and progressed, or if necessary regressed, throughout the eight weeks as deemed necessary for each child. For children who had more severe symptoms of ASD or required more assistance performing an exercise, reinforcement was provided by the instructor with additional demonstrations and by SNAs with further demonstrations of video and picture cues (Case & Yun, 2018). Adaptations to equipment including the use of larger hula hoops, lighter balls or balloons, larger target areas for throwing and external visual aids such as foot markings or handprints were used as needed.

Every one-hour exercise class was divided into a 10-minute warm-up, a 40-minute main phase (which included skill-based activities), and a 10-minute cool-down section. The instructor demonstrated each exercise and visual aids were provided to enhance understanding (see Coffey et al., 2021). Elementary school teachers and SNAs assisted in the coordination of the one-hour class and participated in some activities with the children. Within each school children exercised in their class groups of six children, with one fitness instructor, one teacher, and two SNAs. The INT exercise intensity was monitored by the instructor who would give feedback and encouraged the child during a higher intensity repetition, followed by allowing the child to practice themselves on their own time during a lower intensity repetition. Exercise progression (e.g., throwing a weighted ball through a target) may be reached earlier in an exercise program for a child with mild symptoms of ASD compared to a child with severe symptoms of ASD.

Warm-Up

The 10-minute warm-up consisted of basic movements to physically prepare the children for the exercises to be performed in the main phase, while also serving to familiarise them with the environment, equipment, instructor, and visual supports (i.e., pictures and videos). Movements in the warm-up consisted of walking, running, tiptoeing, and animal movements. They were progressed by adding constraints such as "lifting the knees," kicking heels up," or adding a bean bag to their head for balance and concentration on completing multi-skill movements. The warm-up also consisted of jumping and landing exercises, progressing gradually to multiple jumping sequences such as frog jumps. Finally, some games in the warm-up phase were used, such as "tag," and “mirror,” where children imitated each other doing various movements (see Coffey et al., 2021).

Main Phase

The main phase was designed around the development of INT exercises, using fundamental motor skills (FMS). FMS were performed in stationary activities, dynamic activities (e.g., performing FMS while moving, such as part of races), or applied to games. The FMS section, for example, included throwing and catching, which was introduced in the first week using a beach ball and involved two children throwing a ball a short distance back and forth. As the weeks progressed, the children threw a further distance using a smaller ball or a heavier sports ball (stationary practice). A race was then introduced to challenge the children to throw the ball back and forth several times without dropping the ball (dynamic activities). Finally, for the game section, handball was added using a small ball, which required the children to run passing the ball, focusing on throwing and catching, while also aiming to throw the ball into a bucket/target (games-based activities). As the children progressed, a new game or new phase to a game was added (see Coffey et al., 2021). Each main phase consisted of 5-6 activities within a 40-minute period. Children were encouraged to complete an exercise for a minimum of 5-8 high intensity repetitions within 30s. Exercise progressions were made throughout the program by challenging children to jump higher, jump/ throw a longer distance, or a larger ball included (balloon, volleyball, medicine ball). Progression of the activities occurred in 3 stages: learning the components of the activity, compiling the components of the activity to complete a race, and being able to play a game with others in the activity class (Coffey et al., 2021).

Cool-Down

The 10-minute cool-down consisted of six static stretches, with each stretch held for 20-30s and repeated three times. Stretches typically included the butterfly stretch, alternate toe touch, cobra stretch, knee hug, quad stretch, and arm circles.

Visual Aids

Prior to the commencement of the project, The Story Creator Application (Innovative Mobile Apps Ltd) was uploaded onto a commercial tablet (iPad Air 2, Apple Inc.) and used to create a storyboard including videos of the activities that the children would be asked to participate in. The videos involved another elementary school-aged child performing the exercises. For each activity, the video was embedded with audible and visual text, describing what the child had to do to complete the activity. In addition to the instructor performing the activities, the storyboard was used at the beginning to present the exercises. The instructor held the iPad for the storyboard to be displayed prior to beginning the exercise. For those with severe ASD needing visual reinforcement, teachers and SNAs could display the storyboard on the iPad. Pictures were also used to display key phases of the activities. They were created as a story to follow from the use of The Story Creator Application, which the children could use as a reference mimicking the images. Pictures of the activities were stuck up on the training facility walls for children to use as reference throughout the activity. At the end of each activity, children could move the activity to the “done” section of their schedule and review what was still “to do” on the picture schedule of that day’s exercise class. This was consistent with teaching methods used in a typical ASD unit, providing a picture schedule for children to refer. A standardised protocol of instructional behaviours including video instruction, instructor demonstration, picture reference, prompting and feedback was employed across all study settings.

Statistical Analyses

Test-retest reliability of the modified Eurofit test battery was assessed using intraclass correlation coefficients (ICCs) and coefficients of variation (CV%). A CV% of less than 5% was deemed acceptable (Campbell et al., 2007). Magnitudes of ICC were classified according to the following thresholds: poor <.5, moderate .5-.74, good .75-.9, and excellent >.9 (Koo & Li, 2016). Test-retest reliability was measured on a cohort of 17 children who were not taking part in the intervention. This was implemented in autism classes among children diagnosed with ASD to demonstrate the reliability of our fitness measurements as this area is underexplored. This was completed in 2018 prior to the full collection of the data set and results can be seen in this current study.

Pre-and post-intervention fitness test data were collected to determine if there was a change in fitness levels after the eight-week INT exercise intervention. Data were checked for normality using the Kolmogorov-Smirnov test. Standing broad jump ($p = .200$), sit and reach flexibility ($p = .200$) and handgrip strength ($p = .089$) tests all noted normal distribution. After the cases identified as outliers from the 20 m sprint test were removed (six data points) from the descriptive statistics (pre-and post-intervention), the test of normality noted normal distribution for this variable ($p = .200$). The stork balance test was not normally distributed before ($p < .001$) or after ($p = .002$) removing outliers hence a non-parametric version of a paired samples t-test; Wilcoxon signed ranks test, was used on all data points on the stork balance test. Data points were not removed from the stork balance test as it demonstrates the full attempt from each child, representing the natural variation in the population.

The fitness data were analysed using a 3 (ASD Severity levels) x 2 (time points) analysis of variance (Knapik et al. 2004). Changes in BMI were analysed using pre-and post-testing using a paired samples t-test to review changes over time. Tukey's post hoc analysis was used to identify specific severity level differences. A one-way ANOVA was used to analyse all baseline fitness measurements, to investigate if children of mild, moderate, and severe severity were starting at a similar fitness level or if one group was significantly less fit than other groups. Magnitudes of change between pre-and post-intervention were calculated using Cohen’s (d) effect statistic and interpreted according to the following thresholds: < .20 (trivial), .21-.50 (small), .51 - .80 (moderate) and > .80 (large) (Cohen, 1992). All statistics were computed using Statistical Package for the Social Sciences (SPSS, v.25, Chicago, IL, USA), with statistical significance for all tests set at an alpha level $p < .05$.

Results

Data for the modified Eurofit test indicated excellent relative reliability and acceptable absolute reliability for the 20 m sprint (ICC = .91; CV = 3.27%), standing broad jump (ICC = .98; CV = 2.27%), sit and reach flexibility (ICC = .99; CV = 2.00%), and handgrip strength (ICC = .99; CV = 2.28%) tests. The stork balance test showed excellent relative (ICC = .90) but weaker absolute (CV = 26.7%) reliability.

A comparison of pre- and post-intervention means of each measurement collected can be seen in Table 1. Data indicated a significant decrease in BMI from pre-to post-test ($Z = -2.296$; 78 df; $p < .05$) which reflected a percentage change of 1.17%. More than half of the cohort (54%) were normal weight, with 13% overweight and 33% obese; these percentages were also consistent post-testing. Descriptive statistics on all five Eurofit fitness measures collected pre-and post-intervention demonstrated significant main effects for time ($p < .05$), thus all fitness variables improved after the eight-week INT exercise intervention. All children with ASD attended an average of 95% (22.7 days) of the INT exercise intervention, while incompleteness was less than 12% on all fitness measures.

Table 1. Pre- and post-intervention mean results (95% CI), standard deviation and significance values for the five modified Eurofit tests.

Variable		Pre-intervention		Post-intervention		Effect size		*p*-value
	n	Mean	SD	Mean	SD	d	95% CI	
BMI (kg/m^2)	78	19.58	4.59	19.35	4.47	-0.05	-0.09 – -0.02	0.022
20 m sprint (s)	74	5.55	0.84	5.43	0.98	-0.13	-0.17 – -0.10	0.044
Standing broad Jump (cm)	72	78.79	36.03	92.48	37.39	0.37	0.34 – 0.41	< 0.001
Sit and reach (cm)	76	23.06	6.69	26.15	6.05	0.48	0.45 – 0.52	< 0.001
Hand grip Strength (psi)	77	6.76	2.79	7.35	2.94	0.21	0.17 – 0.24	< 0.001
Stork balance (s)	69	16.09	22.68	32.35	68.38	0.32	0.28 – 0.35	< 0.001

Table 2 contains a comparison of fitness measurements across three severity levels of mild, moderate and severe ASD symptoms. Baseline fitness level measurements of the 20 m sprint, standing broad jump, sit and reach flexibility, and handgrip strength for children with severe symptoms of ASD were significantly lower compared to the fitness levels of children with mild and moderate symptoms of ASD ($p < .01$). For the stork balance test baseline levels were not significantly different among severity groups. At baseline, children with mild and moderate symptoms of ASD had similar fitness levels, with no significant differences between those with mild and moderate ASD symptoms. Graphical representations of the five modified Eurofit testing items compared between the three severity groups pre- and post-intervention are presented in Figure 2.

Table 2. Pre- and post-intervention ASD symptom severity adjusted mean results, standard deviation, effect size and significance values for the five modified Eurofit tests.

Variable	Time Point	Mild (n=22)		Moderate (n= 23)		Severe (n= 33)	
		Mean	SD	Mean	SD	Mean	SD
20 m Sprint (s)	Pre	5.46	0.68	5.39	0.96	5.75	0.84
	Post	5.17	0.69	5.29	1.01	5.77	1.01
	Cohens *d*	0.44		0.10		-0.02	
	p	0.36		0.08		0.08	
Standing Broad Jump (cm)	Pre	94.43	25.91	85.95	37.24	61.43	35.27
	Post	110.76	30.38	100.55	38.78	72.43	32.29
	Cohens *d*	-0.59		-0.39		-0.33	
	p	0.01		0.02		0.01	
Sit & Reach (cm)	Pre	26.43	6.97	24.09	5.87	19.94	5.76
	Post	28.25	7.29	27.32	5.03	23.84	5.07
	Cohens *d*	-0.26		-0.60		-0.74	
	p	0.03		0.01		0.01	
Handgrip Strength (psi)	Pre	8.07	3.16	7.57	2.59	5.31	1.95
	Post	8.57	3.04	8.29	2.96	5.86	2.17
	Cohens *d*	-0.17		-0.26		-0.27	
	p	0.02		0.02		0.01	
Stork Balance (s)	Pre	14.09	15.29	24.44	33.05	11.56	17.73
	Post	21.59	25.20	61.17	116.55	23.79	39.42
	Cohens *d*	-0.37		-0.44		-0.41	
	p	0.10		0.04		0.01	

Significant *time x group* interaction effects are noted in a post-hoc analysis (Table 3) and were evident for standing broad jump ($F(1,68) = 23.587$ $p < .001$), sit and reach flexibility ($F(1,72) = 32.132$ $p < .001$) and handgrip strength ($F(1,73) = 17.992$ $p < .001$). From the post-hoc analysis of the five fitness variables, individuals with severe symptoms of ASD ($d = .02 – .74$) experienced trivial to moderate significant increases as compared to the groups with mild and moderate ASD symptoms.

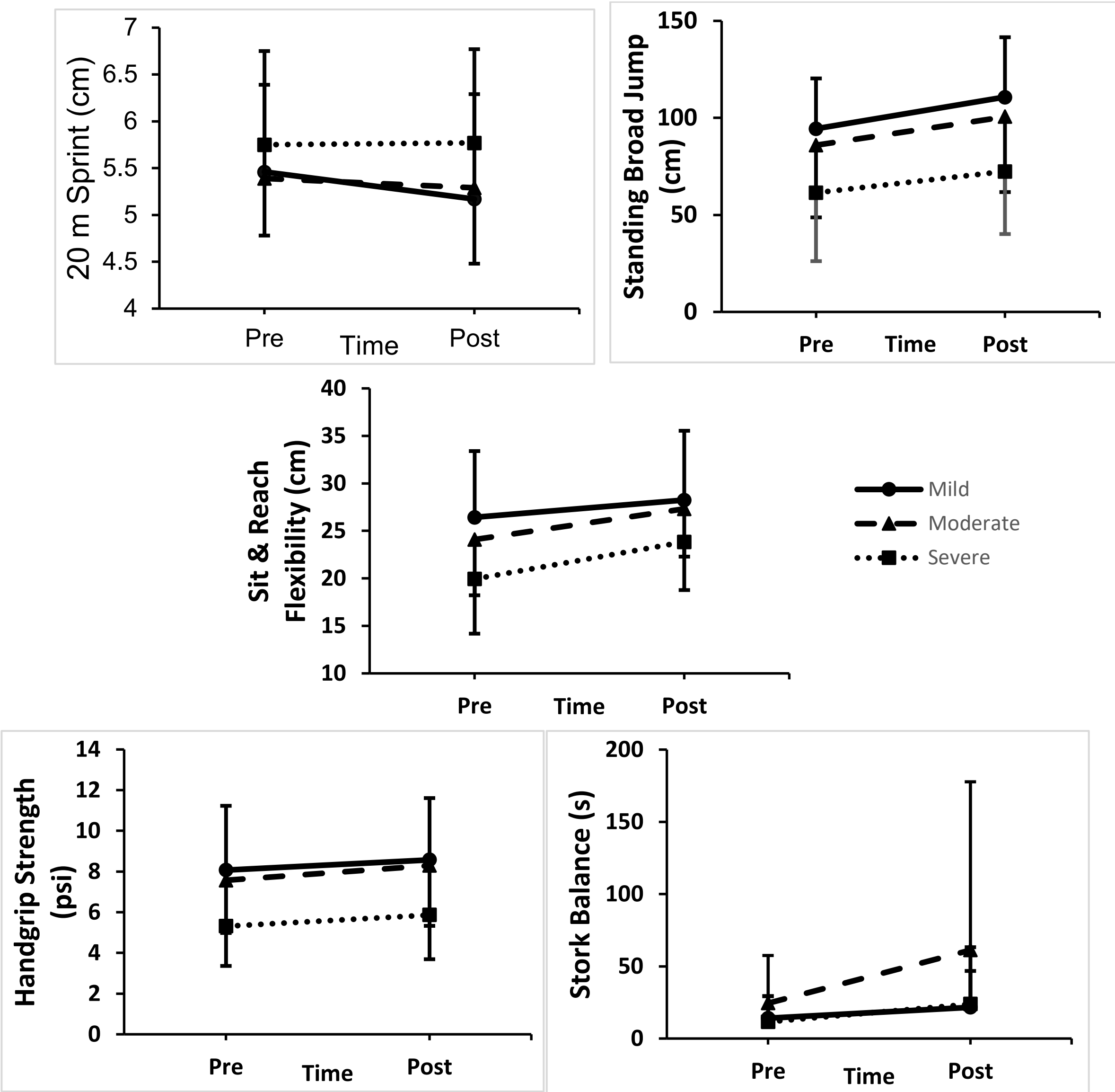

Figure 2. Five physical fitness variables (20 m sprint, standing broad jump, sit and reach flexibility, handgrip strength and stork balance) pre and post changes over an eight week period after the implementation of an INT exercise intervention.

Table 3. Statistical significance (p -values) from post-hoc analysis of a 3x2 ANOVA comparing severity of mild vs moderate ASD symptoms, moderate vs severe ASD severity and mild vs severe severity on each of the five modified Eurofit tests.

Variable	Mild vs Moderate	Moderate vs Severe	Mild vs Severe
20m Sprint (s)	.999	.068	.075
Standing Broad Jump (cm)	.596	.012	.001
Sit & Reach (cm)	.593	.042	.002
Handgrip Strength (psi)	.869	.004	.001
Stork Balance (s)	.912	.238	.093

Discussion

The current study aimed to investigate the effects of a structured school-based INT exercise intervention on the fitness levels of children with ASD and determine whether responsiveness was mediated by the severity of ASD. Findings on the full cohort of children indicate significant improvements for 20 m sprint, standing broad jump, sit and reach flexibility, handgrip strength, the stork balance test, and BMI. Moreover, children with severe symptoms of ASD achieved greater significant improvements in fitness measures following the INT exercise intervention in comparison to children with mild and moderate symptoms of ASD. This study extends upon the evidence for INT programs for improving the fitness of children without ASD (Sañudo et al., 2019) to children with ASD.

The findings demonstrate the potential of a school-based INT exercise intervention to offset the physical fitness disparities experienced by children with ASD, with significant improvements seen for muscular strength, anaerobic fitness, balance, and flexibility. The positive findings reflect prior research demonstrating improvements in physical fitness of children with ASD following aquatic interventions (Fragala-Pinkham et al., 2011; Pan, 2011; Yilmaz et al., 2004), community-based exercise interventions (Cheldavi et al., 2014; Pitetti et al., 2007), and school-based exercise interventions (Lourenco et al., 2015; Wuang et al., 2010). Due to the INT intervention being school-based, low-cost, and with few equipment and facility needs, this intervention modality may be a scalable and sustainable means of addressing physical fitness disparities among children with ASD, ultimately reducing their risk of illnesses and injuries (Fraser et al., 2020; Kujala et al., 1992; McGuine et al., 2000; Ortega et al., 2008; Willems et al., 2005). Based on this study's findings, further testing of INT interventions using experimental research designs is now required.

This study reinforces the positive effects of INT exercise interventions in children with ASD and more specifically with severe symptoms of ASD. Children with severe symptoms of ASD experienced significantly greater increases in standing broad jump, sit and reach flexibility and handgrip strength in comparison to those with mild and moderate ASD symptoms. This may be due to children with more severe symptoms of ASD having lower baseline fitness scores, thus having more opportunity to attain greater improvements compared to the individuals with mild or moderate symptoms. The significant improvements in fitness variables among children with severe symptoms of ASD are encouraging. Our baseline data demonstrate that children with more severe symptoms with ASD are most at-risk of low physical fitness; this is unsurprising as children with severe symptoms of ASD engage in lower levels of physical activity participation compared to children without ASD and those with milder symptoms of ASD (Healy et al., 2017; Memari et al., 2015; Pace & Bricout, 2015; Pan et al., 2016; Pan, 2011; Scharoun et al., 2017; Tyler et al., 2014). Thus, our findings reinforce the need to specifically target the children with more severe symptoms of ASD and highlights the potential of INT interventions as a promising exercise modality for these children.

The current study's findings suggest INT exercise interventions could potentially be an effective school-based intervention for children with ASD. This finding reflects data from the neurotypical school-age population (Sañudo et al., 2019). In a systematic review of 14 studies, Sañudo and colleagues (2019) reported improvements associated with INT interventions including stability, movement skills, strength, agility, speed, and fatigue resistance. Moreover, research has shown that INT can elicit greater gains in health and skill-related fitness than standard physical education when performed twice weekly for 15 minutes (Faigenbaum et al., 2011). For schools, teachers, and parents or guardians, INT interventions are cost- and time-effective modalities enhancing motor skills and promoting physical activity among both boys and girls (Faigenbaum et al., 2014), highlighting the potential effectiveness and applicability of INT interventions in school settings for children with ASD.

Limitations

Certain limitations should be considered when interpreting findings from the current study. Firstly, due to the nature of ASD, some children were unwilling to perform some test items pre-intervention and refused on more than one occasion. However, incompleteness was less than 12% on all measures. Secondly, although adherence to the INT exercise intervention was high with 95% of total sessions completed, the amount of exercise completed by each participant likely varied. Future research should seek to objectively measure the intensity of exercise engaged in by participants. Thirdly, this study employed a single-group, repeated measures design; future research should seek to replicate the study utilizing a non-exercising control group. Despite these limitations, the current study makes an original and significant contribution to the literature, indicating the positive role structured exercise interventions can have on selected physical fitness measures.

Perspectives

There is a critical need to improve health and fitness levels in children with ASD. This study demonstrates that the introduction of a structured school-based INT exercise intervention has the potential to improve the fitness levels of elementary school-aged children with ASD, with more significant improvements noted in children with severe ASD symptoms. Implementing INT exercise interventions for this population may provide children with ASD the skills and fitness necessary to participate in exercise and sports activities. There is a need for further research to analyse if more tailored exercise interventions are needed for children of different severity levels of ASD to optimize their effects (Blagrave 2017).

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