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Effect of Sensory-Motor Integration Trainings on Executive Functions and Social Interactions of Children with High Functioning Autism Disorder

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Abstract

Background: Autism spectrum disorder (ASD) is a neurodevelopmental disorder that appears in the early years of childhood.
Objectives: This study aimed to examine the impact of sensory-motor trainings on the executive functions and social interactions of children with high-functioning autism.
Methods: The current research was of semi-experimental type and pre-test-posttest research design with control and experimental groups. The sample consisted of N = 50 boys aged 7 to 12 years with high-functioning autism in Shiraz. A selective sampling approach was used to randomly allocate 50 high-functioning autistic students into experimental and control groups. Initially, a pretest was administered using the Coolidge Personality and Neuropsychological Inventory for Children and the Gilliam Autism Rating Scale. Subsequently, the experimental group engaged in 24 sessions of sensory-motor integration trainings three times a week over 8 weeks, while the control group continued with their regular daily activities. Data analysis was performed using covariance analysis.
Results: The findings indicated that therapeutic intervention through sensory-motor integration trainings led to significant enhancements in the executive functions and social interactions of children in the experimental group ($P \leq 0.05$). Conversely, no improvements were observed in the control group.
Conclusions: The results of this study suggest that sensory-motor trainings programs can effectively enhance the executive functions and social interactions of children with high-functioning autism.

Keywords: Sensory, Autism, Executive Function, Social Interaction

1. Background

Autism spectrum disorder (ASD) is classified as a pervasive developmental disorder characterized by a range of behavioral symptoms such as aggressive or self-injurious behaviors, atypical responses to social stimuli, and extreme self-reliance (1, 2). According to the World Health Organization report on March 30, 2022, nearly 1 out of every 100 children is diagnosed with autism (3). In Iran, clinical experience has shown that the number of children with autism has increased in recent years (4). Autism spectrum disorder children face many difficulties in acquiring and using communication skills (5, 6). Currently, major weaknesses in verbal and non-verbal communication and social interaction are considered as part of the diagnostic criteria for children with ASD (7). Problems related to the inability of autistic children to communicate and express their needs are associated with inappropriate behaviors, also causing the child to withdraw from society, become depressed, and fail in daily and academic activities, with anxiety and depression disorders being long-term complications (8). There is strong evidence that children and adults with ASD also have weaknesses in certain cognitive processes (9), such as executive functions (8). Deficits in executive functioning may be accompanied by other deficits such as cognitive inflexibility, preservation, and inappropriate responses to social situations among these children (4, 6). In a recent study, it was shown that the severity of impairments in the executive functioning of autistic children varies at different ages, sometimes even becoming more severe in older children (10). In another study on children with high-functioning autism, a significant association was found between impaired executive functions and the triad of symptoms in autism, which includes deficits in communicational skills and social skills as well as repetitive behaviors (11). Given the importance of executive functions in the everyday life and social development of autistic children, and considering the relationship between social development, behavioral dimensions, and academic competence, many interventions have been designed in this regard (12). However, these treatments are expensive and time-consuming, making the development of cost-efficient treatments highly necessary (6, 13). One of these interventions that has attracted the attention of autism specialists is interventions based on physical activity (6). The benefits of participating in physical activities have been identified in normal children and children with developmental disorders (6, 13). One of the movement interventions currently used for autistic children is sensory-motor integration trainings (14). Sensory-motor integration programs involve controlled sensory stimulation that structures meaningful, self-directed activities in such a way as to elicit an adaptive response and improve motor and behavioral responses by integrating tactile, deep, and vestibular sensory inputs (15, 16). This approach is in actuality a method of processing information in such a way that the brain selects, reinforces, inhibits, and compares information to allow the integration and organization of the input data into a flexible model. Researchers have suggested that a high percentage of patients with ASD exhibit some form of abnormality in sensory processing (14). In other studies, researchers have found that sensory integration leads to increased social interactions and verbal ability among children with autism (14, 17). In contrast, some studies have found no increase in the cognitive and educational skills of children with ASDR after sensory-motor training (18). Considering the immense impacts of sensory-motor abnormalities on individuals suffering from ASD in terms of their social, academic, and communicational functioning, it seems necessary to introduce interventional programs that effectively alleviate the problems in this domain.

2. Objectives

Therefore, the present study was designed and implemented to extend the empirical evidence and test the effectiveness of sensory-motor integration trainings on the executive functions and social interactions of children suffering from high-functioning autism.

3. Methods

3.1. Subjects

The current research was of semi-experimental type and pre-test-posttest research design with control and experimental groups. The statistical population included boys with high-functioning autism who were referred to the Shahid Farazdaghi Center of Shiraz, Iran in 2023. According to the statistical criteria and previous similar studies, the sample size was N = 50 children with an average age of 7 to 12 years (19). The participants were selected by availability sampling and were randomly and equally divided into the experimental and control groups, with each group comprising 25 subjects.

3.2. Apparatus and Task

3.2.1. Coolidge Personality and Neuropsychological Inventory for Children

The coolidge personality and neuropsychological inventory for children (CPNI) is a test that evaluates several neurocognitive and behavioral disorders in children and adolescents aged 5 - 17 years. This test is answered by parents using a Likert Scale. In this test, each disorder has specific subscales; two of these subscales assess executive functions across 19 items across the three areas of organizing, decision-making/planning and inhibiting. Given that scores are allocated to children depending on their behavioral problems, a high score in each subscale indicates a large number of problems in the related domain. The reliability of the scoring items related to the areas of organizing, decision-making/planning, and inhibiting were found to be 0.85, 0.60, and 0.74, respectively (20).

3.2.2. Gilliam Autism Rating Scale

The Gilliam Autism Rating Scale (GARS) has been validated as a standard reference tool for diagnosing and assessing the severity of impairments in individuals with ASD. This scale has three subscales of stereotyped behaviors, relationships and social interactions, each of which has 14 items. The second edition of GARS is completed by direct observation as well as interviews with parents and teachers of children with ASD. The child's caregivers are asked to rate the child's behaviors based on the frequency of their occurrence over a six-hour period on a four-point rating scale ranging from zero (absence of the specified behavior) to three (repeated observation of the specified behavior). The raw score for stereotyped behavior is converted to a standardized score with a mean of 10 and a standard deviation of 3. The psychometric properties of the GARS have been reported as acceptable with reliability of 0.88 to 0.96 (Gilliam, 1995). For the Persian version of the second edition of GARS, the Cronbach's alpha coefficient was 0.89 (7).

3.2.3. Wechsler Intelligence Scale for Children

Wechsler Intelligence Scale for children (WISC) is an analytical test for children aged 5 to 15 years, in which scoring is based on the degree of success and includes 12 subtests. These sub-tests are divided into two groups of verbal features (general knowledge, general perception, numerical problems, similarities, vocabulary and numerical memory) and non-verbal (completing pictures, arranging visual stories and cubes, connecting parts, solving mazes). Its overall internal consistency is 0.96 and its Verbal and Non-verbal Scales are reported as 0.94 and 0.90 respectively. And based on retest reliability (more than one month), the overall scale has a reliability of 0.95 and the Non-verbal Scale has a reliability of 0.90 (21).

3.3. Intervention

The sensorimotor training program was based on Kurtz's intervention program and included seven axes of physical awareness, motor planning, bilateral motor integration, balance skills, fine motor coordination, visual performance skills, and oral motor skills (22). The trainings related to these seven axes were performed in each session in the order mentioned. Examples of trainings for each field are presented in Table 1.

After each session, data related to dependent variables were collected after ten minutes of rest. Written consent was obtained from the parents of all autistic children. Parents were comprehensively informed about the topic, method and importance of the research. The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki, as reflected in the prior approval of the Institute's Human Research Committee.

3.4. Procedure

Inclusion criteria included an age range of 7 to 12 years, trainable children with a minimum intelligence quotient (IQ) of 70, the male gender, and informed parental consent for participation in the study. Simultaneous participation in similar studies, undergoing any other concurrent interventions, lack of regular attendance at treatment sessions, and having seizures during the treatment process were considered as the exclusion criteria (23). The Wechsler intelligence test was conducted by a psychologist to determine the children's IQ levels. Then, the experimental group was exposed to the intervention program of sensory-motor training across 24 sessions (8 weeks, 3 sessions per week, and 45 minutes per session). It should be noted that before and after the intervention program, questionnaires were completed regarding the executive functions (by parents) and social interactions (by experts) of all the children. The control group performed their routine daily activities during the research period and did not participate in any regular physical or motor activity training programs.

3.5. Data Analysis

To describe the variables of the study, the mean and standard deviation were used. In the inferential data analysis, after checking the normality of the data using the Shapiro-Wilk test, the covariance analysis test was used to test the hypotheses. All data were analyzed using SPSS software version 22, and the significance level was considered as $P \leq 0.05$.

4. Results

In this study, to describe the demographic variables related to the participants, the means and standard deviations for the age, weight, and height of the subjects in the control and experimental groups were evaluated, with the results presented in Table 2.

Before the analysis of covariance, regression homogeneity, and variance homogeneity were evaluated using Levene's test, and the normal distribution of the dependent variables was checked for using the Shapiro-Wilk test. Results showed that the distribution of all dependent variables in both the experimental and control groups were normal ($P \geq 0.05$).

As seen in Table 3, differences existed between the mean scores of the experimental and control groups in the pre-test and post-test. In the next step, the covariance analysis test was used to determine the significance of the mentioned differences, the results of which are presented in Table 4. After statistically controlling for the pre-test effect, there was a significant difference between the pre-test and post-test scores of children in the experimental group in the subscales of executive functions and social interactions ($P \geq 0.05$). In

Table 1. Intervention Program

Sessions	Contents	Time (min)	Example of Intervention
First	Body awareness	30 - 45	Pushing the floor coverings against the wall, walking on the chest, walking on the back
Second	Motor planning	30 - 45	Imitating the sequence of multiple movements, crossing the obstacle with different order and methods
Third	Bilateral motor integration	30 - 45	Cutting pictures with the dominant and non-dominant hand, filling the glass with rice grains while the dominant hand is holding the glass
Fourth	Skills balance	30 - 45	Carrying the cubes on the board, walking between the lines and stepping on the marked position
Fifth	Fine motor coordination	30 - 45	Untying the knots, filling the gap, turning the coin between the fingers
Sixth	Functional vision skills	30 - 45	Drawing a figure with the light of a hand lamp on the wall of a dark room, following the light
Seventh	Oral motor skills	30 - 45	Blowing bubbles, moving the ball in different directions

Table 2. Demographic Characteristics of Research Participants

Groups	Age (y)	Height (cm)	Weight (kg)
Experimental	9.96 ± 3.10	134.03 ± 6.25	29.60 ± 5.84
Control	9.85 ± 3.15	136.01 ± 5.30	32.40 ± 4.93

other words, sensory-motor training led to better executive functions and social interactions in children with high-functioning autism.

5. Discussion and Conclusions

The results regarding the effect of sensory-motor integration exercises on the social interactions of these children showed a significant difference between the mean scores of the experimental and control groups. This finding is in line with the results of many studies (13, 18, 23, 24), but inconsistent with the results of several studies (14, 25). To explain this inconsistency, the varying nature and severity of ASD, as well as the individual differences between participants, particularly in their cognitive, social, and speech skills, should be noted. Furthermore, as Dowd et al. have emphasized, social skills are very complex constructs that are difficult to measure in individuals with ASD, and differences may be due to the different tools that researchers Use to measure and assess these skills (26). Goodway et al. argues that in childhood, the socialization process begins with sports activities, because children generally value being active in play, sports, and leisure activities, and the importance of play and motor activity is that Through these activities, the child learns about himself, his body, his abilities and his relationships with others (27). Another important explanation behind the effect of the specified exercises on social interaction is the fact that the child is present among peers and friends and plays with them during the exercises (28, 29). In the present study, children in the experimental group performed the exercises in groups of several individuals, which resulted in interactions with their peers and thereby improved their social interaction skills. Neurobiological mechanisms related to exercise are revealed at both extracellular and intracellular levels (6, 28). At the extracellular level, angiogenesis occurs as a physiological process in which new vessels grow from existing vessels and is associated with neurogenesis (formation of neurons from neural stem cells) in the hippocampus (4, 18). Furthermore, motor activity increases the heart rate and strengthens the cardiac muscles, which ultimately leads to improvements in the circulatory system, tissue oxygenation, and cognitive functioning (8, 28). Another finding of the present study was that sensory-motor trainings have a positive effect on the executive functions of children with high-functioning autism. This finding is also consistent with the results of many studies (6, 28-31). The results of the present study are in line with the literature regarding the relationship between executive functions and autistic symptoms In explaining the effectiveness of sensory-motor training on executive functions, psychological and biological factors should be emphasized, because success in performing motor exercises can lead to increased self-esteem and improved social performance (18). The biological factor is related to the monoamine hypothesis, which states that as motor activity increases, norepinephrine, serotonin, and dopamine neurotransmitters increase in the brain, leading to a rise in both arousal and attention (14). Proponents of motor exercises recommend that physical objects, toys, and other visual materials should

Table 3. Mean and Standard Deviation of Scores Related to Executive Functions and Social Interactions in the pre- and Post-tests for Each Group

Variables	Mean ± SD
Organizing	
Experimental	
Pre-test	20.19 ± 0.359
Post-test	24.43 ± 0.240
Control	
Pre-test	20.10 ± 0.460
Post-test	18.99 ± 0.362
Planning	
Experimental	
Pre-test	19.39 ± 0.350
Post-test	23.63 ± 0.332
Control	
Pre-test	19.42 ± 0.423
Post-test	18.11 ± 0.329
Working Memory	
Experimental	
Pre-test	17.07 ± 0.312
Post-test	20.87 ± 0.265
Control	
Pre-test	17.27 ± 0.321
Post-test	16.15 ± 0.160
Inhibiting	
Experimental	
Pre-test	17.40 ± 0.396
Post-test	21.27 ± 0.310
Control	
Pre-test	17.91 ± 0.322
Post-test	17.07 ± 0.243
Social Interactions	
Experimental	
Pre-test	20.43 ± 0.764
Post-test	24.97 ± 0.341
Control	
Pre-test	20.77 ± 0.544
Post-test	18.37 ± 0.314

be used in the training of autistic children and that attention should be paid to the visual learning experiences of these children since learning is the basis of sensory-motor exercises (16, 32). To explain this finding, it is necessary to consider the point that according to Baresh's theory, human learning requires movement and is shaped when motor actions such as the balancing of large and fine muscles as well as general body coordination develop normally (27). Sensory-motor trainings reinforce the child's intelligent behaviors and provide a better basis for thinking, planning, organizing, and monitoring (18, 30). Motor activities augment the children's skills in seeing, visually adapting, recognizing objects, understanding distances, and understanding concepts related to themselves, all of which all related to executive functions (33, 34). The findings of this research are consistent with the theory of dynamic systems in which, in addition to heritage, the environment also plays an important role in the development process (35). Factors such as facilities, equipment, adequate time allocation, and encouragement play key roles in helping children develop and improve children's cognitive and motor skills (29). The field of sports interventions is another factor affecting the results obtained in the present study, which probably facilitates learning, because the

Table 4. Covariance Analysis test Results for Comparing Executive Functions and Social Interactions of Children in the Control and Experimental Groups

Source of Change	Sum of the Squares	Df	Mean Squares	F	P-Values	Effect Size
Organizing						
Pre-test	21.35	1	21.35	31.19	0.001	0.53
Group	217.07	1	217.07	317.15	0.001	0.92
Planning						
Pre-test	17.47	1	17.47	19.42	0.001	0.41
Group	228.96	1	228.96	254.60	0.001	0.90
Working memory						
Pre-test	11.64	1	11.64	40.32	0.001	0.59
Group	173.84	1	173.84	601.57	0.001	0.95
Inhibiting						
Pre-test	22.64	1	22.64	60.91	0.001	0.69
Group	148.32	1	148.32	398.88	0.001	0.93
Social interactions						
Pre-test	6.52	1	6.52	4.53	0.042	0.24
Group	330.78	1	330.78	230.625	0.001	0.89

implementation of therapeutic interventions in such a way that the conditions and environments are attractive and stimulating can lead to more child involvement and encourage them to continue further education (28, 31). Finally, it can be said that providing activities appropriate to the child's ability level can reduce the feeling of frustration and fear of failure in the child, and as a result, it leads to better recovery (27, 36).

In general, the results of the present study indicate that sensory-motor training is a useful and enjoyable intervention for children with autism, with the ability to improve social interactions and executive functions. Although more research is needed to determine the mechanisms underlying the training of executive functions and social interactions of children with ASD, but it seems necessary to consider sports-oriented programs in the weekly schedule of these children due to the ease of implementation and saving treatment costs. One of the limitations of the present study was the failure to evaluate the differences of the participants (gender, individual characteristics, and especially the severity of ASD) and to examine the retention stage. Therefore, it is recommended to investigate these issues in future research.

Footnotes

Authors' Contribution: Conception and design of the study, A.H, MH. Z; data collection, A.S; data analysis and/or interpretation, A.H, A. S; drafting of manuscript and/or critical revision, MH.Z, A. H; approval of final version of manuscript, A.S, A.H.

Conflict of Interests Statement: The authors declare that there is no conflict of interest.

Data Availability: The dataset presented in the study is available on request from the corresponding author during submission or after publication.

Ethical Approval: The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki, as reflected in the prior approval of the Institute's Human Research Committee. Ethical considerations include informing parents about the design, potential benefits, nature and duration of the research, using an intervention that does no harm; confidentiality of data related to children and parents; the option was to withdraw from the study at any time and prioritize treatment goals over research goals.

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Informed Consent: Written consent was obtained from the parents of all autistic children. Parents were comprehensively informed about the topic, method and importance of the research.

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