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Original article

The Impact of a Game-Based Motor-Cognitive Training Program on Improving Fine Motor Skills and Response Inhibition in Children with Attention Deficit Hyperactivity Disorder

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Abstract: *Objective* — The goal of this study was to determine the effectiveness of a game-based motor-cognitive training program in improving fine motor skills (FMS) and inhibiting impulsive responses in children with attention deficit hyperactivity disorder (ADHD).
Methods — This study was a quasi-experimental study using a pre-post design with a control group. Thirty boys were selected using convenience sampling from two clinics in Tehran and randomly distributed among two groups: experimental and control (n=15). The intervention consisted of a game-based motor-cognitive training program including 10 sessions of 40 minutes each. Data collection instruments included the short form of the Bruininks-Oseretsky Test of Motor Proficiency, second edition (2BOT) and Stroop Test for response inhibition. Data were analyzed performed using SPSS v.27 software and covariance analysis (one-way ANCOVA and MANCOVA).
Results — In this study, a significant difference was observed between the experimental and control groups in improving attention and inhibiting impulsive responses after the intervention ($p<0.001$). The game-based intervention was significantly more effective in improving FMS and inhibiting impulsive responses in children with ADHD vs. the control group ($p<0.001$). Considering the results of the pre-test, significant differences were found between the experimental and control groups in at least one of the dependent variables (components of FMS) ($P<0.001$, $F=15.800$).
Conclusion — Based on our findings, the game-based motor-cognitive training program is effective in improving FMS and response inhibition in the treatment of cognitive and motor impairments.

Keywords: Play therapy, motor-cognitive training program, fine motor skills, response inhibition, ADHD.

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Introduction

Attention deficit hyperactivity disorder (ADHD) is a common developmental disorder characterized by impulsive and hyperactive behavior. This disorder affects children, making it difficult for them to concentrate on one thing. ADHD can seriously impact areas such as schoolwork or employment [1]. It is a developmental and neurological disorder that begins in childhood [2] and is associated with inadequate activity, uncontrolled behavior, and working memory shortfall [3]. It can lead to impairments in social, educational and professional activities, as well as motor skills. This disorder can cause defects in psychological, emotional, and cognitive information processing in children [4].

ADHD leads to problems in organizing behavior, preventing people from concentrating better [5]. The prevalence of this disorder worldwide is approximately 6%, and it is considered the most common neuropsychiatric disorder among children [5]. There is evidence of reduced cognitive flexibility in people with ADHD, which is reflected in difficulties adapting behavior to different situations or changing cognitive sets or executive functions [5]. Executive functions are higher cognitive and metacognitive functions that play a role in regulating thinking and goal-directed behavior [6]. They may include a set of higher abilities for self-initiation, strategic planning, cognitive flexibility, and impulse control [7]. Executive functions can be described as indicators of when and how to perform behavioral functions that help people plan goal-directed actions, suppress inappropriate responses, demonstrate flexibility, and predict behavior [8]. Skills such as working memory, response inhibition, sustained attention, mental flexibility, planning, emotion regulation, problem-solving skills, and self-awareness are related to executive functions [8].

On the other hand, fine motor skills (FMS) are fundamental to children's development and influence the progress of writing skills and daily activities. However, the development of these skills is a multifaceted process influenced by various factors. Hence, understanding the differences in the development of FMS in children and the factors influencing this development is essential [9]. FMS require the coordination of the small muscles of the hand, fingers, and eyes and allow us to perform the movements necessary for some daily activities, such as writing, drawing, making small objects, typing, buttoning, etc. [10]. FMS are defined as movements of small muscles requiring close hand-eye coordination. At a practical and concrete level, FMS has various designations (e.g., manual dexterity, visual-motor coordination,

manual control, manual dexterity skills, and visual-motor integration) [11].

FMS are important abilities for learning and achieving success in school. Movement and learning are the source of all perceptions and cognition. In accordance with the problems of motor activity in students, sensorimotor integration is one of the treatment methods based on perceptual-motor theories [12]. Sensory integration is based on the theory of Ayres (1989), according to which a person interprets sensory perceptions of the environment, combines and integrates them for maximum use [13].

Studies have shown that the motor activity of students with ADHD is characterized by either high or low intensity, or a significant developmental delay [14]. A study investigating the effect of the Darshan Motor Activity Program on gross motor skills in children with sensory integration disorders showed that this program improves them in this group of children [14]. Another study examined the effectiveness of teaching basic motor skills in 6-year-old boys and girls. The results showed that motor therapy leads to improvements in FMS and gross motor skills in children with intellectual disabilities [15].

On the other hand, impaired response inhibition is a fundamental deficit in ADHD and is considered the core of the disintegration of information processing processes in the executive functions of this disorder [16]. Response inhibition is the ability to stop or refrain from responding, or, in other words, the ability to think before acting [17]. Numerous studies indicate a deficit in executive functions, including response inhibition and sustained attention, in children with ADHD [18]. For example, some studies showed that children with ADHD have impairments in inhibition, organization, and planning [19, 20]. Yasumura et al. (2019) showed that the development of the frontal lobe in these children is delayed, leading to inefficiency of executive functions, such as working memory, planning, and organization [20]. Currently, there are many methods used to help children with ADHD and children with learning disabilities, and to improve their abilities. Among these methods, play therapy should be mentioned. Play therapy is an interpersonal, dynamic, active, and constructive relationship between a person and a therapist, and the therapist strives to create a safe environment and relationship for self-discovery and self-expression through play, preparing appropriate tools for play [21]. Child-centered play therapy (CCPT)1 is a practical and recommended non-pharmacological intervention for children with ADHD. Studies have been conducted regarding the effects of CCPT with a motor-cognitive approach. Amini et al. (2022) showed that sensorimotor integration exercises and computerized cognitive rehabilitation are effective for executive functions (working memory, response inhibition, and cognitive flexibility) in children with ADHD [22]. Karimian and Barzegar (2022) showed that CCPT is effective in correcting attention deficit in students with ADHD, as well as in students with learning disabilities, and the observed difference vs. the control group was statistically significant. Based on the above reasoning regarding the importance and consequences of deficits in response inhibition and motor skills in children with ADHD, it is necessary to conduct safe and sustainable interventions [23].

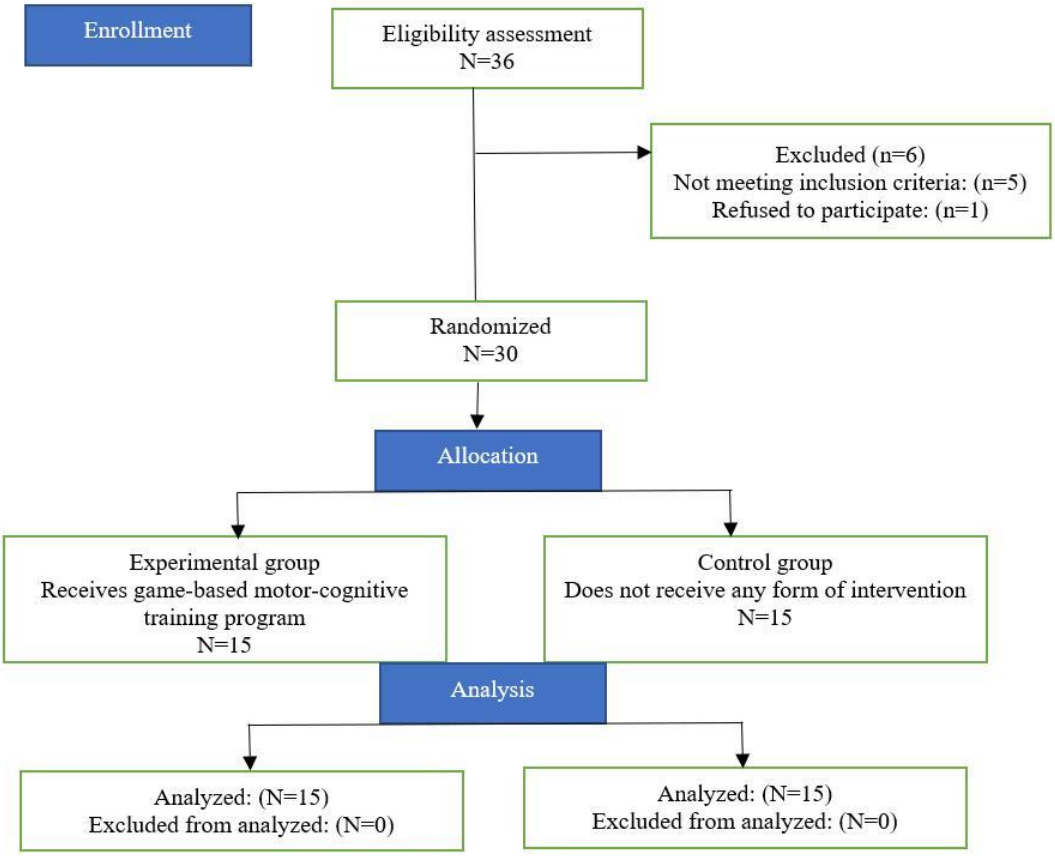

Figure 1. Flowchart of study design.

Table 1. Attention and response inhibition in participants of the experimental and control groups during the preliminary (pre-test) and final testing (post-test) phases

Component		*Control group*				*Experimental group*			
		Pre-test		Post-test		Pre-test		Post-test	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Stroop Test for response inhibition									
Number of errors		2.11	1.03	2.31	1.17	1.14	0.67	2.38	1.46
Number of correct answers		29.79	6.10	30.40	6.92	36.15	7.10	31.26	6.18
Reaction time to stimulus	Consonant	1,274.61	114.19	1281.34	115.34	1,068.24	198.66	1,279.19	115.52
	Dissonant	1,127.30	179.100	1187.61	186.208	1,055.11	148.34	1,259.50	190.17
Interference index		7.09	2.98	6.77	2.11	2.63	1.77	6.81	2.13
Fine motor skills test									
Reaction speed		2.12	0.85	1.81	0.66	3.26	0.94	1.89	0.64
Visual-motor control		2.35	0.88	2.11	1.02	3.11	1.27	1.86	1.16
Upper limb speed and dexterity		6.91	4.23	6.79	4.38	10.22	5.09	6.75	4.41

Table 2. Normality tests for response inhibition and fine motor skills

Variable	*Kolmogorov-Smirnov test*			*Shapiro-Wilk test*		
	P	df	Statistics	P	df	Statistics
Response inhibition	0.198	29	1.667	0.238	29	1.218
Attention	0.208	29	1.511	0.655	29	1.901

Since the mentioned interventions have a lower cost and no side effects compared to chemical drugs, and in cases where drug treatment is ineffective or not preferred by parents and patients, confirming the effectiveness of these interventions can be an optimal alternative to other treatment methods [24]. In addition, due to the lack of studies comparing and combining the effectiveness of different treatment methods to identify various treatments, and due to the presence of multidimensional problems in patients with ADHD, a motor-cognitive therapy approach is proposed [25]. Studies have been conducted on students with intellectual disabilities using video games to improve concentration, and the results showed an improvement in perceptual ability, which in turn led to an improvement in their learning ability [26, 27]. Although game-based cognitive training programs have been studied for their appeal and effectiveness in various target groups, there is a lack of research on children with ADHD. Therefore, this study investigated a game-based motor-cognitive educational approach to improving response inhibition and FMS in children with ADHD.

Methods

Study design

This study was a quasi-experimental study with a pre-post design with experimental and control groups.

Participants

The study included 30 boys with ADHD aged 6-13 years (mean age: 9 years) from two clinics in Tehran, Iran, who were selected using convenience sampling procedure. Participants were randomly divided into two groups: a control group (n=15) and an experimental group (n=15) (*Figure 1*).

Selection criteria

Inclusion criteria: diagnosis of cognitive-motor impairments associated with hyperactivity; and living with parents.

Exclusion criteria: symptoms of neurodevelopmental disorders or severe health problems; participation in any other concurrent educational programs.

Data collection instruments

In this study, the Stroop Test for response inhibition and the Bruininks-Oseretsky Test of Motor Proficiency, second edition (2BOT) were used to collect data.

Stroop Test. In this study, it was used to measure response inhibition. The Stroop test (color version) was first developed in 1935 by Ridley Stroop to measure selective attention and cognitive flexibility. The Stroop test is one of the most important tests used by researchers to measure response inhibition. It has been translated into various languages such as Chinese, German, Swedish, Japanese, etc. The Stroop Test is not a single test, but there are various versions of it developed for research purposes. In this study, the Persian version of the computerized Stroop Test was employed [28]. This test presents 48 words denoting colors (the color of the word matches the meaning of the word; red, yellow, green, and blue) and 48 words denoting colors but written in a different color (for example, the word *'blue'* written in red), with a stimulus presentation interval of 800 milliseconds and a stimulus presentation duration of 2,000 milliseconds. The subject's task is to select only the color. Correct answers, incorrect answers, no answers, reaction time to matching words, and reaction time to non-matching words in the Stroop Test are calculated by the computer. The Persian version of the Stroop Test has acceptable validity and reliability [29]. The reliability of this test (based on retesting) ranges from 0.80 to 0.91 [30].

Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (2BOT). The 2BOT test is a suitable instrument for measuring a wide range of motor skills in individuals aged 4 to 21 years. The 2BOT test is a revised version of the Bruininks-Oseretsky Test of Motor Proficiency (1978), which was developed to assess motor proficiency or impairments in movement and coordination in children [31]. The short form versions of the 2BOT motor proficiency test include 12 items that measure 8 subscales. The subscales of this test measure fine motor precision, fine motor integration, manual dexterity, bilateral body coordination, balance, speed and dexterity, upper body coordination, and strength. In general, these 8 subscales measure 4 motor domains: fine manual control, manual coordination, body coordination, and strength and dexterity [32]. The concurrent validity of this test with the short form of the Bruininks-Oseretsky Test of Motor Proficiency (SF-BOTMP) is 0.88, and its reliability across three age ranges from 4 to 21 years is 0.81-0.90.

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Table 3. The results of the homogeneity test of regression slopes and Levine's test

Component	*Levine's test*				*Homogeneity of regression slopes*				
	P	F	df2	df1	P	F	MS	df	SS
Number of errors	0.651	1.29	25	1	0.083	1.01	102.16	1	102.16
Number of correct answers	0.435	2.06	25	1	0.271	0.27	235.46	1	235.46
Reaction time to consonant stimulus	0.920	1.28	25	1	0.104	0.29	2,150.97	1	2,150.97
Reaction time to dissonant stimulus	0.377	1.95	25	1	0.063	1.60	1,902.14	1	1,902.14
Interference index	0.200	1.66	25	1	0.513	0.88	501.24	1	501.24
Response speed	0.605	1.44	25	1	0.177	1.11	492.18	1	492.18
Visual-motor control	0.105	1.20	25	1	0.543	0.16	583.01	1	583.01
Upper limb speed and dexterity	0.441	1.92	25	1	0.191	0.43	3,390.04	1	3,390.04

Table 4. Results of one-way analysis of covariance (ANCOVA) comparing post-test values of the variables in the experimental and control groups

Source of changes	*Sum of squares*	*df*	*Mean square*	*F*	*Significance level (p-value)*	*Eta coefficient*	*Statistical power*
Pre-test	9,400.241	1	9,400.241	316.201	0.0001	0.81	1.00
Group fine motor skills	1,076.931	1	1,076.931	77.139	0.0001	00 0.67	1.00
Error	5,140.105	13	6,631.430	-	-	-	-
Pre-test response inhibition	843.24	1	178.05	342.20	342.20	0.001	0.68
Group	103.93	1	104.78	99.17	99.171	0.001	0.69
Error	983.49	13	196.69	-	-	-	-

Table 5. Results of multivariate analysis of covariance (MANCOVA) of post-test mean scores in the experimental and control groups against the pre-test data

Variable	*Test name*	*Value*	*df Theory*	*df Error*	*F*	*P*	*Eta coefficient*	*Statistical power*
Fine motor skills	Pillai's Effect Test	0.919	3	17	15.800	0.001	0.71	1.00
	Wilks' Lambda Test	0.135	3	17	69.215	0.001	0.71	1.00
	Hotelling's T-square Effect Size	0.209	3	17	251.110	0.001	0.71	1.00
	Roy's Largest Root Test	1.218	2	8	243.903	0.001	0.71	1.00
Response inhibition	Pillai's Effect Test	0.965	3	17	18.807	0.001	0.74	1
	Wilks' Lambda Test	0. 035	3	17	69.204	0.001	0.74	1
	Hotelling's T-square Effect Size	228	3	17	251.660	0.001	0.74	1
	Roy's Largest Root Test	1.228	2	8	134.671	0.001	0.74	1

Intervention programs

The intervention consisted of a game-based motor-cognitive training program involving 10 sessions of 40 minutes each (Experimental group).

Data analysis

Intragroup and intergroup analysis of normally distributed data (based on Kolmogorov-Smirnov and Shapiro-Wilk statistical tests) was performed using one-way analysis of variance (ANOVA) and multivariate analysis of covariance (MANCOVA). The statistical significance level was set at $p<0.05$. SPSS Statistics v.27 software was used for data processing.

Results

Table 1 presents descriptive information on attention and response inhibition scores in the experimental and control groups at the pre- and post-test phases.

Based on the results in *Table 1*, it can be seen that for all components of the response inhibition test (number of errors, number of correct answers, reaction time to a consonant stimulus, reaction time to a dissonant stimulus, and interference index), as well as for all components of the FMS test (reaction speed, visual-motor control, speed and dexterity of the upper limbs), there is a difference between the pre- and post-test scores in the experimental and control groups. In other words, the test results in the experimental group improved relative to the pre-test results better than in the control group.

To test the hypotheses, the assumptions of covariance analysis were first checked. The results of the normality test for data distribution are shown in *Table 2*.

According to the values obtained from the Kolmogorov-Smirnov and Shapiro-Wilk statistical tests (*Table 2*), it can be concluded that the distribution of pre-test scores for response inhibition and FMS in children with ADHD is normal ($P>0.05$). Therefore, parametric statistics can be used to test the hypotheses.

Table 3 presents the results of the test for homogeneity of regression slopes and Levene's test for assessing the equality of variances.

As can be seen from *Table 3*, the assumption of homogeneity of regression slopes and equality of variances of response inhibition scores and FMS scores in experimental and control groups is confirmed. Therefore, the null hypothesis, i.e., homogeneity of regression slopes, is accepted, and covariance analysis is permissible ($P>0.05$).

Given the confirmation of the prerequisites for using multivariate covariance analysis, a one-way analysis of covariance (ANCOVA) and a multivariate analysis of covariance (MANCOVA) of the components of the Stroop Test were performed in the experimental and control groups. *Table 4* presents the results of ANCOVA comparing the post-test values of variables in the experimental and control groups.

As shown in *Table 4*, regarding the FMS variable, when controlling for baseline data (pre-test scores), a statistically

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significant difference is observed between the experimental and control groups for attention (P=0.001; F=316.201). Thus, the third hypothesis is confirmed. In other words, the game-based motor-cognitive training program proved effective in improving FMS in children with ADHD in the experimental group vs. the mean score in the control group. The effect size or difference is 0.81. That is, 81% of the individual differences in post-test results for FMS are associated with the effect of the game-based motor-cognitive training program. The power of the test is 1, which means that there is no probability of a Type II error.

Also, when controlling for baseline (pre-test) scores, a significant difference is observed between the experimental and control groups in for response inhibition (P=0.001; F=342.20). Thus, the first hypothesis is confirmed. In other words, the game-based motor-cognitive educational program proved effective in improving response inhibition in children with ADHD in the experimental group vs. the mean score in the control group. The effect size or difference is 0.86. That is, 86% of the individual differences in post-test results for response inhibition are associated with the effect of the game-based motor-cognitive training program. The power of the test is 1, which means that there is no probability of a Type II error.

To test the effectiveness of each component of attention, a multivariate analysis of covariance (MANCOVA) was employed, and the statistical significance of each component of the FMS and response inhibition variables in the samples was measured. The results of this test are shown in *Table 5*.

As can be seen from *Table 5*, when controlling for pre-test results, the significant levels of all tests show that there is a statistically significant difference between the children with ADHD in the experimental and control groups in at least one of the dependent variables (components of FMS): P<0.001; F=15.800.

The effect size or difference is 0.71, meaning that 71% of the individual differences in post-test results for FMS components are related to the effect of the game-based motor-cognitive training program. The statistical power is 1, which means that there is no probability of a Type II error.

Also, when controlling for pre-test values, the p-values of all tests show that there is a significant difference between the experimental and control groups in at least one of the dependent variables (components of response inhibition): P<0.001 and 807/18=F. The effect size or difference is 0.74, meaning that 74% of the individual differences in post-test scores for response inhibition components are related to the effect of the game-based motor-cognitive training program. The statistical power is 1, which means that there is no probability of a Type II error.

Discussion

Childhood is one of the most important stages of life, in which a person's personality is formed [32]. ADHD is a developmental and neurological disorder that begins in childhood [2, 33]. This disorder is associated with inadequate activity, uncontrolled behavior, and working memory deficits [3]. It can lead to impairments in social, educational and professional activities, along with motor skills. Also, it can cause defects in psychological, emotional, and cognitive information processing in children [34].

Based on our findings, there is a statistically significant difference between the experimental and control groups in terms of FMS with the pre-test control. Hence, we concluded that this significant difference between the mean values of the two groups is due solely to the intervention of the game-based motor-cognitive educational program.

These findings are consistent with the results of other authors [16, 22, 23]. The impact on attention deficit in students with ADHD and students with learning disabilities is effective, which is consistent with other studies [5, 17, 35, 36] that concluded that physical exercise and training movements improve the level of executive functions and reduce attention deficit in children with ADHD. Wong et al. (2023) also showed that physical activity plays an effective role in the development of inhibitory functions in children with ADHD [37].

The significant difference in the mean scores of the experimental group vs. the control group can be explained by the fact that CCPT is a method in which the natural means of expressing a child's state (i.e., game) are used as a therapeutic method [16]. It helps children control their stress and emotions [38]. Using games and toys, people can express their thoughts, feelings, and concerns that they cannot express without feeling themselves threatened, through the symbolic and objective representation of toys. According to Kleeren et al., 2023, motor interventions generally improve motor skills in children with ADHD [39]. The central role of experience in the game allows children showing their problems and reactions to the world around them by demonstrating their creativity, which makes it possible to transform play into a therapeutic intervention in a dynamic form. Regarding the need for games, Association for Childhood Education International (ACEI) pointed to the need for games suitable for each age group of children and emphasized the important role of play in their development [16]. Within the skill-based approach, it is assumed that children can achieve higher levels of motor development through reinforcement and targeted practice [40].

We revealed is a statistically significant difference between the test and control groups in terms of response inhibition (based on the pre-test control) and concluded that it is caused solely by the intervention being a game-based motor-cognitive educational program.

These results are consistent with other studies [22, 36, 41, 42]. The effectiveness of CCPT in improving response inhibition as one of the important executive functions was noted as well. In their study, Davis et al., 2015, examined various components of executive functions (including inhibition) in children with ADHD before and after participating in a computer-based educational program [43]. In addition, Arsham and Rahmani (2020) considered the role of motor coordination as an effective factor in predicting the executive functions of elementary school students [6].

The significant difference in the mean scores of the experimental group and the control group is explained by the fact that the CCPT approach emphasizes the child's participation in treatment. In play therapy based on the cognitive behavioral model, this is implemented by focusing on aspects such as self-control and control over others, mastering and accepting responsibility for behavioral change, and acquiring social skills. This type of play therapy uses methods such as self-control and addiction management techniques (such as positive reinforcement, behavior shaping, self-silencing, and role modeling); hence, the ultimate goals are social development and improvement of social skills towards reducing behavioral problems and adaptation. In the process of play therapy, children learn that

displaying undesirable behavior, aggression, negative emotions, and conflict behavior can lead to rejection from those around them and their friends. Thus, children are explained that their behavior is a matter of their choice, through which they can also choose the consequences of their behavior, and this awareness helps them strengthen self-control, as a result of which they exhibit better response exhibition [44]. The latter is the ability of a student to concentrate on (or ignore) thoughts or ideas associated with behavioral responses, and it is an executive function skill that is related to judgment, self-control, and problem-solving [45].

Conclusion

Based on the results of this study, the game-based program of motor-cognitive training is effective in improving FMS and response inhibition in children with ADHD. Hence, this method is recommended for use by psychoanalysts and counselors in treatment facilities. Furthermore, the ease of using such programs, their attractiveness to children, and the need for children to improve cognitive motor functions make it advisable to implement these programs in counseling and family centers, preschools, and schools for children with special needs as part of the educational program.

Limitations of the study

The limitations of this study included the fact that, due to time constraints, it was not possible to track the results of the intervention. It was also impossible to re-contact some of the study participants.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional Ethics Committee and with the 1964 Declaration of Helsinki and its later amendments.

Conflict of interest

No conflicts of interest are declared by the authors.

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