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Original Article

Effects of Yoga Training on Cognitive Performance and Anxiety of Children with ADHD

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Abstract

Background: The influence of yoga training and its associated exercises on anxiety and cognitive functioning in children diagnosed with ADHD is a relatively neglected field of research. This study aimed to investigate how engagement in a yoga exercise program affects cognitive abilities, particularly attention and memory, alongside anxiety levels in children diagnosed with ADHD.

Methods: This study employed a quasi-experimental design, specifically a pretest-posttest approach that incorporated a control group. The study participants were primary school students diagnosed with ADHD in district 5 of Tehran, Iran, during the academic year of 2023-2024. Forty participants were selected through convenience sampling and subsequently assigned at random to either the experimental group, which engaged in yoga, or the control group. The experimental group underwent 16 yoga training sessions, each lasting 45 minutes, scheduled twice a week. Data were analyzed using paired and independent t-tests with SPSS version 27.

Results: The findings indicated a significant improvement in attention scores among the yoga participants during the post-intervention phase (0.495±0.12, P<0.001). Additionally, there was a significant enhancement in both forward and backward working memory scores for these participants in the same phase (9.60±1.42, P<0.001; and 5.80±1.05, P<0.001, respectively). Lastly, the data revealed a significant reduction in anxiety scores for individuals in the yoga group following the intervention (6.95±1.43, P<0.001).

Conclusions: Engaging in practices such as yoga, as outlined in this study, may significantly contribute to alleviating cognitive impairments and anxiety-related issues in children with ADHD.

Keywords: Exercise, Yoga, ADHD, Cognition, Anxiety

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1. Introduction

Neglecting the developmental needs of children can lead to significant and lasting harm to societal health (1). Previous research underscored that young individuals require not only physical care but also comprehensive support across various dimensions of their lives, including social, emotional, personality development, and cognitive abilities (2). This highlights the imperative to focus on both mental and physical health disorders during childhood. Attention Deficit Hyperactivity Disorder (ADHD) is one of the most significant psychological disorders affecting children, representing a critical concern for community mental health (3). The symptoms of ADHD typically emerge before the age of seven, and the behaviors associated with this disorder can lead to considerable difficulties in social, academic, or occupational settings (4). To diagnose ADHD, a minimum of six to twelve behavioral symptoms must be identified in the individual (5). The significance of ADHD is underscored by its high prevalence; approximately 50% of children with psychiatric disorders are affected by it, with estimates indicating that between three to five percent of school-aged children are diagnosed (6). Research indicated that the prevalence of ADHD symptoms is approximately 10.1% among elementary school children, with a notable disparity between genders, 13.6% in male students as compared with 6.5% in female students (2). Recovery from the condition, when it does take place, typically transpires between the ages of 12 and 21, with occurrences

being quite uncommon prior to the age of 12 (4). There are instances where symptoms may improve during puberty; however, in approximately 60% of cases, these symptoms persist into adulthood (1, 6). Generally, hyperactivity tends to diminish with age, yet difficulties with concentration and impulsive behaviors may persist.

ADHD encompasses a range of behavioral challenges characterized by limited attention spans, difficulties in task completion, elevated levels of physical activity, and inadequate social awareness (7). For example, a prevalent issue observed in children with ADHD pertains to their cognitive functions, particularly in the areas of attention and memory (8). Attention constitutes the initial phase of information processing, defined as the capacity to focus on specific elements of environmental stimuli for subsequent analysis, thereby facilitating the development of concentration and awareness (9). A significant issue related to attention in these children is sustained attention, which enables individuals to manage distractions and respond solely to pertinent stimuli (10). Additionally, these children frequently experience difficulties with selective attention, which is the capacity to concentrate on a particular category of information while disregarding extraneous data. This ability is crucial for the functioning of the central executive system (11). In essence, selective attention involves the process of identifying relevant information while filtering out irrelevant distractions, thereby allowing for the effective management of substantial amounts of information (12). Moreover, children with ADHD experience challenges related to working memory (13). While memory is often viewed as a measure of intelligence, it fundamentally serves as a core component of cognitive ability. Currently, working memory is recognized as a significant area of study, garnering considerable interest from researchers (14). As a cognitive framework, working memory facilitates the temporary storage and processing of information necessary for executing a range of intricate cognitive activities (15). In essence, working memory operates as an integrated system that links various subsystems and functionalities of memory (16). Thus, the elevated prevalence of cognitive impairments, including diminished attention and memory skills, in children with ADHD highlights the critical need for the development of effective interventions designed to enhance cognitive functioning within this demographic.

In addition, children diagnosed with ADHD may be directed to occupational therapy not solely due to issues related to attention or hyperactivity, but rather as a result of underlying psychological or cognitive difficulties. Anxiety disorders rank among the most prevalent comorbid conditions associated with ADHD (17-19). The presence of anxiety and its various forms constitutes one of the most widespread mental health issues (20, 21). A comprehensive epidemiological investigation revealed that approximately 10 percent of children and adolescents living in typical circumstances encounter anxiety disorders prior to reaching 16 years of age, a figure that has been rising amid the ongoing crisis (22). Anxiety serves as an evolutionary and adaptive mechanism that enhances performance when experienced at moderate levels; however, it can hinder performance when levels become excessively high (23). These disorders tend to be chronic in nature and can adversely affect physical, cognitive, behavioral, and emotional functioning, thereby elevating the risk of depression and suicidal behavior (21-23). Therefore, the high incidence of anxiety disorders among children diagnosed with ADHD underscored the necessity of identifying effective interventions aimed at alleviating anxiety in this population.

There exists a significant demand for efficient therapeutic approaches aimed at alleviating cognitive and anxiety symptoms in children diagnosed with ADHD. However, despite the availability of diverse treatment modalities, such as pharmacological, behavioral, and cognitive interventions, each approach continues to encounter distinct challenges. One educational approach that has received limited attention in the context of alleviating anxiety disorders and enhancing cognitive function is yoga training. As a form of exercise and physical activity, yoga represents a non-invasive strategy that has proven to be highly effective in preventing or ameliorating cognitive and psychological disorders (24, 25). The primary objective of yoga is to foster behavioral, mental, and emotional well-being through the integration of breath, physical movement, thoughts, and emotions. This practice encompasses specific physical postures, mental focus, and breathing techniques, many of which are incorporated into rehabilitation and physiotherapy programs (26, 27). Prior studies indicated that yoga training can lead to reductions in anxiety and depression levels (24-26).

Additionally, other research demonstrated that engaging in yoga exercises can enhance cognitive processes (28-30). Nevertheless, the impact of yoga training and its exercises on anxiety and cognitive function in children diagnosed with ADHD remains an underexplored area of study. The significance of identifying non-pharmacological approaches and interventions to alleviate disorders in children diagnosed with ADHD, including anxiety and cognitive impairments, underscores the rationale for the present study. Therefore, the present study aimed to explore the impact of participation in a yoga exercises course on cognitive functions, specifically attention and memory, as well as anxiety levels in children with ADHD.

2. Methods

2.1. Design and Participants

This quasi-experimental study used a pretest-posttest design with a control group. The statistical population comprised primary school students diagnosed with ADHD in District 5 of Tehran, Iran, during the year 2023. Following coordination with school authorities and obtaining parental consent, a total of 40 participants were selected through a convenience sampling approach (Figure 1). Subsequently, these participants were randomly and evenly allocated to either the experimental group (Yoga) or the control group, using a simple random sampling method. This process involved the creation of a table of random numbers, with participants assigned to either group in a sequential order based on their corresponding numbers. This approach ensured that each participant had an equal probability of being assigned to either group, thereby minimizing potential biases and confounding variables. In the yoga group, the mean anxiety scores at pretest and posttest were recorded as 48.9±7.34 and 36.40±6.67, respectively, while the control group exhibited mean scores of 49.40±7.73 and 48.90±7.37, respectively (31). The inclusion criteria were: being an elementary school student diagnosed with ADHD, having no prior history of psychiatric medication use, including anti-anxiety and antidepressant medications, and absence of any vision or hearing impairments. Additionally, participants were required not to have engaged in yoga training or similar exercise programs. Those who chose to withdraw from the study or missed more than three yoga practice sessions were excluded from the study.

2.2. Measures

2.2.1. Cognitive Performance

Attention: The Stroop test (32) was used to assess attention. It is a widely recognized assessment tool used to evaluate selective attention. In the present investigation, a computerized adaptation of the Stroop test was employed. This assessment comprises three distinct phases: The initial phase, referred to as the coordinated effort stage, presents the names of the four primary colors in black at the center of the screen. The participants are required to swiftly press one of the designated keys - blue,

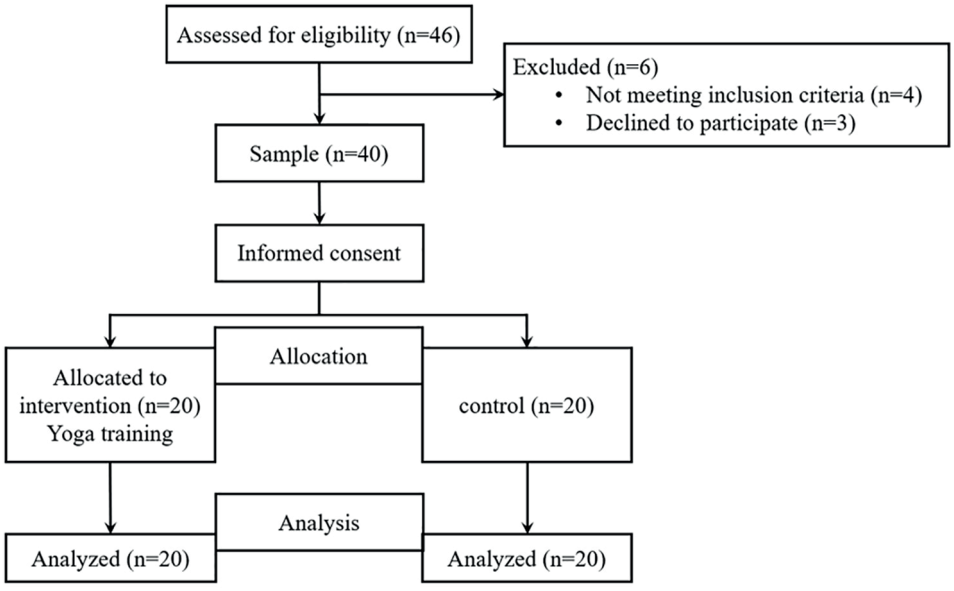

Figure 1: The figure shows the CONSORT flow diagram of the research.

red, yellow, or green - corresponding to the color names displayed. The second phase features the names of the four primary colors, each displayed in its respective color, also centered on the screen. In this stage, participants must quickly press the key that matches each color. The final phase, known as the incoherent effort or interference stage, presents the names of the four primary colors, but each name is displayed in a color that differs from its own. The participants are instructed to press the key that corresponds to the ink color of the word rather than its meaning; for instance, if the word "red" is shown in green, the participant must identify the color of the ink. The key performance metrics in this test include accuracy, measured by the number of correct responses, and speed, assessed by the reaction time of correct responses to stimuli, recorded in milliseconds. In the present study, "accuracy" scores were included in the analysis. A score of 0 was allocated for either a lack of response or an incorrect answer, while a score of 1 was given for each correct answer. The average score was determined by computing the arithmetic mean of the points obtained in each segment of the evaluation, where the highest achievable score was 1 point and the lowest was 0. Additionally, the Cronbach's alpha coefficient was computed and yielded a value of 0.90.

Working memory: The Digit Span subtest of the WISC-IV (33) was employed to assess working memory capabilities. The administration followed the standardized protocols outlined in the WISC-IV, with the exception of the discontinuation rule: The participants engaged in all trials for both digit span forward (DSF; two trials for each list length ranging from 2 to 9) and digit span backward (DSB; four trials at list length 2, and two trials each for list lengths 3 to 8). In this study, the internal consistency reliability for the sample was found to be α=0.85 for DSF and α=0.73 for DSB.

2.2.2. Anxiety

The Revised Children's Manifest Anxiety Scale–Second Edition (RCMAS-2) Short Form (34) was employed to assess anxiety levels. This instrument consists of 10 items and is designed to evaluate general or manifest anxiety among students aged 6 to 19 years. Participants respond to the items on the RCMAS-2 Short Form using a binary yes/no format. The individual responses are combined to generate a total raw score, which ranges from 0 to 10, with higher scores indicating increased symptom severity. The internal consistency reliability for the scores derived from the RCMAS-2 Short Form is reported to be between 0.76 and 0.79. Furthermore, the validity of this tool has been corroborated by eight experts, resulting in a Content Validity Index (CVI) of 0.90 and a Content Validity Ratio (CVR) of 0.92. Additionally, the Cronbach's alpha coefficient for this study was calculated to be 0.94.

2.3. Procedure

Following the acquisition of ethical approval, a sample of 60 students diagnosed with ADHD, who were enrolled in primary schools located in district 5 of Tehran, Iran, was identified. Upon securing consent, 40 students expressed their willingness to participate in the research. These participants were randomly assigned into two equal groups: the yoga group and the control group, employing a simple random sampling technique. The yoga group participated in yoga training, as elaborated in the subsequent section, under the guidance of a certified instructor. Conversely, the control group did not receive any form of intervention during the study period. Both groups underwent pretest and posttest assessments to evaluate their cognitive abilities and anxiety levels. The research was conducted in strict adherence to ethical guidelines.

2.4. Intervention

A summary of the intervention is presented in Table 1. The experimental group participated in 16 sessions of yoga training, each lasting 45 minutes, conducted twice weekly. The yoga sessions were led by a qualified instructor in a group format over a span of two months (eight weeks). The curriculum encompassed two fundamental aspects of yoga: Hatha Yoga and Raja Yoga, along with eight general stages of practice. Hatha Yoga focused on a comprehensive range of physical, breathing, and relaxation techniques (stages 3 to 7), while Raja Yoga emphasized targeted mental and concentration exercises aimed at regulating emotions and thoughts (stages 1, 2, and 8).

2.5. Data Analysis

Descriptive statistics, including mean and standard deviation, was employed to assess the central tendency and variability of the dataset.

Table 1: A summary of the intervention

Session	Objective	Content and exercises
1 and 2	Familiarization and initial explanations	The introduction and welcome, presentation of the group's rules and regulations, explanation of the philosophy, origins, and history of yoga, articulation of the principles and foundations of yoga, and interpretation of the effects of yoga practice on both the body and mind.
3 and 4	Hatha Yoga and Raja Yoga exercises	The introduction of two fundamental branches of yoga, namely Hatha Yoga and Raja Yoga, along with the eight general stages of yoga, is essential. Hatha Yoga instruction encompasses comprehensive physical, breathing, and relaxation practices, corresponding to stages three through seven. In contrast, Raja Yoga instruction focuses on mental exercises and specific concentration techniques aimed at regulating emotions and thoughts, which are associated with stages one, two, seven, and eight.
5 and 6	Individual abilities in Yoga	An examination of individuals' practical abilities in Hatha Yoga and Raja Yoga, supplementary training in Hatha Yoga and Raja Yoga, their practical exercises in the presence of examiners
7 and 8	The foundational principles of yoga	The foundational principles of yoga encompass the instruction of the lotus position, wherein the individual transitions from one side to the other while adopting a prayer-like hand position, facilitating the opening of the hip joints. Additionally, the practice includes warming exercises for both the body and mind, utilizing the sun salutation technique. This involves standing with feet together and arms at the sides, taking a deep breath; as the palms are raised towards the chest, the breath is exhaled. Following this, another deep inhalation occurs while the arms are lifted overhead, accompanied by an exhalation. Subsequently, the individual bends at the waist, engaging in a stretching motion to the extent possible while maintaining deep breathing throughout the stretch.
9 and 10	The continuation of yoga training	The continuation of yoga training includes various poses such as the butterfly pose, the arch pose, the bridge pose, and the cobra pose. For instance, in the butterfly pose, participants are instructed to sit on their knees and bring the soles of their feet together. They should grasp their feet with their hands, ensuring that the heels are positioned close to one another, while simultaneously engaging in deep breathing and performing a stretching action. To add variety, they are encouraged to lift the crown of their head along the spine without rotating the neck.
11 and 12	Training in meditation	Training in meditation for both the body and mind aims to alleviate anxiety, focusing on how to meditate effectively, as well as guidance on the appropriate timing and duration of meditation practice.
13 and 14	Ahimsa	The explanation and instruction of ahimsa (non-violence and the practice of peace and tranquility) is recognized as one of the five components of yama in Patanjali's eightfold path of yoga. This involves understanding individual behaviors following experiences of failure, whether through the expression of violence or its suppression. It also encompasses identifying the underlying causes and factors that lead to the expression and repression of anger, as well as teaching the application of ahimsa to prevent both expressions and suppressions of anger, alongside practicing this skill in the face of adversity.
15 and 16	Summary	The practical application of the skills acquired during yoga training sessions, an examination of participants' perspectives on the intervention process, a summary and synthesis of the sessions, and expressions of gratitude towards the participants.

The Shapiro-Wilk test was applied to evaluate the normality of the dependent variables across all groups. An independent t-test was conducted to compare the baseline data (i.e., pretest) between the groups. Additionally, a paired t-test was used to determine the effects of the yoga intervention on cognitive performance and anxiety levels. The threshold for statistical significance was established at $P<0.05$. Data analysis was performed using SPSS version 27.

3. Results

The study involved a sample of 40 children diagnosed with ADHD, evenly split between an experimental group participating in yoga and a control group. This sample included 16 female and 22 male individuals, all of whom were enrolled in grades two through four of primary school. The ages of the participants ranged from 8 to 10 years, with a mean age of 9.12±0.63 years. Specifically, the average ages for the yoga group and the control group were 9.15±0.60 years and 9.10±0.67 years, respectively, with no statistically significant differences identified between the two groups ($P=0.729$). In the yoga group, there were 11 boys (55.0%) and 9 girls (45.0%), while the control group included 12 boys (60%) and 11 girls (40%). The analysis indicated no significant statistical differences between the groups in terms of gender distribution ($P=0.846$ and $P=0.871$, respectively).

Table 2 illustrates the attention scores obtained before and after the intervention for both the yoga and control groups. The findings indicated a notable enhancement in attention scores among the yoga participants during the post-intervention assessment ($P<0.001$).

Table 2: Pre- and post-intervention attention scores in the yoga and control groups

Variables	Phase	Group		Inter-group comparisons
		Yoga	Control	
		M±SD	M±SD	
Attention	Pretest	0.367±0.11	0.363±0.13	t=0.112 P=0.550
	Posttest	0.495±0.12	0.375±0.13	t=2.916 P=0.006
	Intra-group comparisons	t=-12.813 P<0.001	t=-1.831 P=0.083	

SD: Standard Deviation

Table 3: Pre- and post-intervention working memory scores in the yoga and control groups

Variables	Phase	Group		P (Inter-group comparisons)
		Yoga	Control	
		M±SD	M±SD	
Forward	Pretest	8.10±1.91	8.05±2.11	t=0.078 P=0.938
	Posttest	9.60±1.42	8.10±1.41	t=3.341 P=0.002
	P (intra-group comparisons)	t=-6.381 P<0.001	t=-0.252 P=0.804	
Backward	Pretest	4.60±1.35	4.55±1.09	t=0.128 P=0.899
	Posttest	5.80±1.05	4.60±0.88	t=3.899 P<0.001
	P (intra-group comparisons)	t=-6.000 P<0.001	t=-0.271 P=0.789	

SD: Standard Deviation

Table 4: Pre- and post-intervention anxiety scores in the yoga and control groups

Variables	Phase	Group		P (Inter-group comparisons)
		Yoga	Control	
		M±SD	M±SD	
Anxiety	Pretest	8.25±1.25	8.35±1.53	t=-0.226 P=0.822
	Posttest	6.95±1.43	8.40±1.35	t=-3.291 P=0.002
	P (intra-group comparisons)	t=4.772 P<0.001	t=-0.438 P=0.666	

SD: Standard Deviation

Table 3 illustrates the working memory scores obtained before and after the intervention for both the yoga and control groups. The findings indicated a notable improvement in both forward and backward scores among the yoga participants during the post-intervention assessment (P<0.001).

Table 4 illustrates the anxiety scores obtained before and after the intervention for both the yoga and control groups. The findings indicated a notable reduction in anxiety scores among participants in the yoga group during the post-intervention assessment (P<0.001).

4. Discussion

The present study aimed to examine the impact of participation in a yoga exercise program on cognitive functions, specifically focusing on attention and memory, as well as anxiety levels in adolescents diagnosed with ADHD. The results of the study indicated that involvement in a yoga intervention led to a notable enhancement in attention and working memory performance. These findings were consistent with previous research conducted on children populations (24, 26, 27, 29) and suggested that yoga practices may

be beneficial in enhancing cognitive abilities in children diagnosed with ADHD. The effectiveness of yoga on working memory in children diagnosed with ADHD can be elucidated by understanding the nature of this neuropsychological condition. Recent theoretical frameworks highlight that ADHD is characterized by significant deficits in attention and cognitive functions (9, 11, 13, 15). Individuals with ADHD often struggle with response inhibition, working memory, planning, and maintaining alertness (14, 16). Engaging in physical activities such as yoga can induce physiological changes that positively influence these deficits (23, 26, 35, 36). Specifically, yoga can regulate the cardiovascular system by impacting the parasympathetic autonomic nervous system and stimulating the vagus nerve, which in turn diminishes the action potential in the heart's sinus atrial node. This process aids in calming the nervous system and alleviating attention deficits, thereby enhancing working memory (35, 37). Furthermore, yoga practice fosters positive responses and creates environments that distract individuals from anxiety-inducing stimuli. Additionally, such physical activities bolster the deep nervous and vestibular systems, leading to improvements in higher cognitive functions, including motor skills and action integration. This supportive environment can mitigate the symptoms of ADHD and enhance motor abilities, ultimately fostering greater self-confidence and a sense of self-efficacy (26, 27, 29, 32).

Then, the results of this study revealed that participating in a yoga intervention has resulted in a significant reduction in anxiety scores. The findings aligned with earlier studies involving children (25, 27-29) and suggested that yoga practices may be beneficial in reducing anxiety in children diagnosed with ADHD. The impact of yoga training on alleviating anxiety can be articulated through its incorporation of specific breathing techniques, which encompass inhalation, retention, and exhalation (29, 30). Engaging in these breathing exercises facilitates a reduction in the prevalence of negative thoughts and emotions, including judgment, fear, anxiety, and worry. Conscious breathing practices foster an environment conducive to non-judgmental observation, non-reactivity, and mindful action. Consequently, individuals can liberate themselves from habitual behavioral responses, diminishing the control that anxiety exerts over them (24, 26, 28). This transformation is achieved through a process of understanding and re-acceptance, leading to a heightened awareness of their emotional state and a subsequent reduction in anxiety intensity. Furthermore, yoga practices have been shown to lower plasma catecholamine levels and significantly diminish sympathetic nervous system activity, thereby positively influencing brain function by decreasing stress-related hormones (29, 30, 35, 37). Given that anxiety adversely affects cognitive and emotional processes, the primary benefit of yoga lies in its capacity to induce relaxation, which in turn mitigates stress and anxiety, enhancing overall quality of life. While yoga does not serve as a cure for medical conditions, it offers individuals a more favorable perspective on their challenges, fostering a positive outlook and direction in life. In light of the considerable stressors present in contemporary society, yoga training can facilitate a swift return to daily routines and enhance life quality by promoting a focus on both physical and mental well-being (25, 27, 29). Additionally, yoga represents a valuable non-pharmacological approach to expedite recovery from various disorders, alleviate disease complications, and cultivate positive psychological attributes, particularly a sense of tranquility, vitality, and health (25, 27).

4.1. Limitations

This study had certain limitations. Firstly, the exclusive focus on elementary school children may hinder the applicability of the findings to other age groups within the ADHD population. Moreover, reliance on convenience sampling, although being practical, could introduce biases that affect the external validity of the results. Additionally, the failure to account for the social and economic backgrounds of the participants may restrict a thorough understanding of the effectiveness of yoga interventions and other factors that influence cognitive function and mental health of children with ADHD. Lastly, the absence of a follow-up assessment may prevent the evaluation of the long-term effects of yoga on the variables measured.

5. Conclusions

Children diagnosed with ADHD often encounter a range of cognitive and mental health challenges

alongside various life difficulties. Engaging in practices such as yoga, as outlined in this study, may significantly contribute to alleviating their cognitive impairments and anxiety-related issues. Therefore, based on our findings, it is recommended that educational and training programs for exceptional children incorporate a variety of exercise techniques, including yoga, to enhance the management of mental disorders such as ADHD in children.

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Authors' Contribution

Sara Bagheri: Substantial contributions to the conception and design of the work, acquisition, analysis, and interpretation of data for the work, drafting the work and reviewing the work critically for important intellectual content. Monir Rostamabadi: Substantial contributions to the conception and design of the work, acquisition, analysis, and interpretation of data for the work, drafting the work and reviewing the work critically for important intellectual content. Sedigheh Khajeh Aflatoon Mofrad: Contribution to the design of the work, drafting the work and reviewing it critically for important intellectual content. Sholeh Khodadad Kashi: Contribution to the design of the work, drafting the work and reviewing it critically for important intellectual content. Valiollah Shahedi: Acquisition, analysis, and interpretation of data for the work, 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 Institute Ethics Review Board with the code of IR.IAU.PIAU.REC.1403.010. Also, written informed consent was obtained from the parents of the children.

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