



Effect of Motor Exercises on Serum Level of Brain-Derived Neurotrophic Factor and Executive Function in Children with Dysgraphia

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Abstract

Background: Students with dysgraphia often find it challenging to organize, prioritize, and store information. These problems are known as poor executive function. On the other hand, the performance of motor exercises can affect cognitive and executive functions through the secretion of nerve growth factors.

Objectives: The present study examined the effect of motor exercises on the serum level of the brain-derived neurotrophic factor (BDNF) and executive function in children with dysgraphia.

Methods: In this interventional study, 40 male third to fifth grade students with dysgraphia were selected through purposive sampling and randomly allocated to experimental and control groups. The exercise program including a set of motor exercises selected from the Lincoln-Oseretsky motor development scale was implemented for 12 weeks (three 45-minute sessions per week). Blood samples were taken 48 hours before the first session and 48 hours after the final session of fasting participants. Moreover, the Wisconsin card sorting task (WCST) was implemented to examine students' executive function.

Results: The analysis of covariance, Pearson correlation, and regression analysis were employed to analyze the data ($P < 0.05$). Results showed that, after a course of motor exercise, the serum level of BDNF and executive function were significantly increased. Moreover, results indicated a significant relationship between the serum level of BDNF and executive function.

Conclusions: The present study revealed that motor exercises may improve executive function in children with dysgraphia by increasing the level of BDNF.

Keywords: Serum Level, Brain-Derived Neurotrophic Factor, Executive Function, Dysgraphia

1. Background

Dysgraphia is a common specific learning disorder (SLD) in students, referring to a serious issue in skills related to writing. This disorder is realized in the form of poor handwriting, spelling mistakes, and errors in composition. Dysgraphia is mostly realized in the form of grammatical errors, punctuation mistakes, poor sentence formation, numerous spelling errors (including missing words or letters, changing the order of letters, failing to distinguish similar letters, mistakes related to letters with an Arabic origin in the Persian script, ...), and a very poor handwriting (1). The process of writing is a complex process depending on numerous skills and capabilities. Writing requires an accurate understanding of symbolic-ideographic models. Furthermore, it requires visual-motor skills

which, in turn, needs eye movement coordination; hand fine motor and gross motor coordination; and arm, hand, and finger muscle control. The word dysgraphia is applied to students who demonstrate writing-related disorders. This term is used for children who write very poorly despite having a normal IQ level. These children cannot perform the motor actions required by writing or copying letters, words, or shapes, or convert visual data into motor actions. The existence of these problems in motor coordination, fine motor, or gross motor skills causes a problem in cognitive processes, including executive functions (2). Executive function is an umbrella term for all complex cognitive processes necessary in performing targeted activities (1), including the ability to respond, program sequences of action, and memorize mental schemata required for tasks in the working memory (2). Hale consid-

ers executive function as planning, flexibility, inhibition, production, and monitoring of action. Another definition for executive functions considers them as composed of two main components, namely mental transference and active memory update. Executive functions evolve along the process of growth and as the child grows up, gradually helping the child perform more complex and difficult tasks (3). Executive functions play a major role in targeted movements and motor control (4). The components of executive function affect performance in reading, mathematics, and writing. These components also determine the level of academic achievement and the students' academic performance. Students with dysgraphia find it challenging to store, organize, and prioritize information and focus on details instead of main points (3). These weaknesses are known as problems with executive functions realized in most academic problems. Therefore, one can conclude that the working memory fails to regulate information due to a problem with data organization and prioritization. This can cause a discord in potential capabilities and performance in these students (5).

Studies on individuals with dysgraphia have found two methods effective in improving executive functions: The first is the use of cognitive exercises to improve cognitive functions and, thus, resolve dysgraphia, while the second one is the use of physical exercises. Rudock, for instance, emphasizes the strong relationship between brain and body. According to them, activities (especially physical activities) in the cognitive domain improve memory and executive function. Research indicates that those with dysgraphia perform significantly more poorly in motor skills (6). Owen emphasizes the importance of fine motor skills (performed by small muscles in the hand) in developing mechanical skills necessary for writing. On the other hand, gross and fine motor skills are inter-related, that is, if one has problems with fine motor skills, he/she will probably find it difficult to perform gross motor skills using large muscles (1). At any rate, fine motor problems (especially eye-hand coordination problems) lead to uncoordinated movements which, in turn, lead to dysgraphia (2). Over the past decades, the benefits of physical exercise on health and brain function have been demonstrated (7). Motor exercises activate the neural network and its communications throughout the body, thereby providing the opportunity for motor and cognitive learning. The performance of exercise and movement is among the best methods for enhancing brain capabilities and paving the way for optimal learning (6). Moreover, regular exercise is known as a key to improving cognitive function (7). It is believed that physical activity and playing play major roles in the natural maturity and executive function of children (8). On the effect of physical activity on children's cognitive function and

academic achievement, Cebli (2003) performed a meta-analysis and examined 44 studies. reporting that physical activity is significantly related to children's cognitive function (8). Therefore, one cannot claim that, since physical exercise needs concentration, memory, cause analysis, and motor skill control, these improvements are related to experiencing mental tasks by children while performing physical exercise and movement. In addition to the effect of physical exercise and movement on cognitive function, various intermediary factors are introduced for the effect of physical activities on the health of the brain and the neural system. Brain-derived neurotrophic factor (BDNF) is part of the family of nerve growth factors, enhances the health, function, and survival of neurons (1), passes both blood-brain barriers (9), and helps protect neurons against free radicals (10). In addition, as a factor affected by physical exercise, it may be related to the function of the brain or other parts of the neural system related to learning and cognitive function. Researchers have observed a direct relationship between BDNF and the nervousness and formation of the upper parts of the brain, including the hippocampus (10). This factor may also play a role in learning-related processes and has a direct relationship with long-term memory (5). BDNF activates intra-cellular neurotransmitter paths involved in cell proliferation, differentiation, and survival, thus playing a major role in cognitive function and especially learning- and memory-related processes (11). Based on studies, nerve growth factors including the BDNF, play a significant role in the evolution of synaptic communications on the spinal cord surface, increase the diameter of the spinal cord, and thus transfer sensory-motor messages across the spinal cord more quickly. These axonal and synaptic changes on the surface of the spinal cord play a major role in motor evolution (12). Studies suggest a reduction in nerve growth factors, especially BDNF, in those with dysgraphia, and the motor disorder in this group is somehow linked to a reduced level of this growth factor (13). The BDNF is a factor linking physical activities, brain structural changes, and cognitive function (14). Physical activity can vary the level of BDNF circulation in healthy individuals (15). Furthermore, enriching the environment by increasing social interaction and providing more opportunities for performing physical activity can have positive effects on perceptual-motor function (16). Moreover, it has been stated that regular exercise is positively linked to improved cognitive function and learning perceptual-motor skills in children (8). Fernandes reports that the secretion of BDNF which depends on brain activity, especially the prefrontal cortex, is of utmost importance in motor learning (17). Previous studies have examined the effects of physical activity (running) and motor and cognitive learning on increasing the expression of

the BDNF gene in various parts of the neural system such as spinal cord, cerebellum, and hippocampus (18). Furthermore, increasing the level of BDNF on the motor cortex has been reported following physical exercise and motor learning (19). Therefore, considering the reduced serum level of BDNF in those with SLD and the positive relationship between levels of BDNF and motor learning and cognitive functions, physical exercise can be used for this students. Data on the effect of various types of physical activity on levels of BDNF are mostly contradictory (20). Zulades et al. examined the effects of 5 weeks of physical exercise on the level of BDNF. They reported that exercise significantly increased the baseline level of this factor. Nevertheless, Schiffert et al. reported that 3 months of exercise in healthy young individuals increases the release of this factor but has no effect on its post-exercise plasma levels. Munoz et al. (21), found that 10 weeks of strength training has no effect on the baseline and post-exercise levels of this factor in young people. They also reported that exercise does not have a significant effect on short and intermediate-term memory of these people. Coelho et al. (18), concluded that 5 weeks of slow exercise temporarily increases the post-exercise level of this factor in healthy inactive people. These exercise-induced changes have rarely been examined on molecular and memory changes. Therefore, as no evidence exists for the simultaneous examination of the effect of physical exercise on executive function and BDNF, the present study seeks to examine how the level of BDNF and executive function in children with dysgraphia are affected by motor exercise.

2. Objectives

The present study aimed to investigate the effect of 12 weeks of motor exercise on the serum level of BDNF and executive function in students with dysgraphia.

3. Methods

The present study is an applied quasi-experimental controlled research with a pretest-posttest design. The research population comprised all male students in the 3rd - 5th grades of primary school. Of these, 40 students with dysgraphia visiting the SLD clinics in Tehran to receive therapeutic-educational services were selected through purposive sampling. Clinics were asked to invite the parents of these students to a meeting. The child symptom inventory was given to instructors and parents so that students with specific behaviors or emotional diseases would be discerned. The researcher interviewed parents in the same session on research objectives, method, and significance. The researcher also obtained written consent for

students' participation from parents. Then, a researcher-made form including demographic information (age, level of education, father's and mother's occupation, and medications) was given to students, and the Raven's coloured progressive matrices (RCPM) was administered. This test was administered in order to assess the IQ level of students with SLD (as an inclusion criterion). Moreover, to ensure the absence of constructional apraxia in students with SLD, the block test was employed (as graphic activities require the writing skill, and if a child has problems with writing or hand fine motor skills, his/her inability to perform these tasks cannot be construed as apraxia). In the second step and following sample selection, students were randomly allocated to the experimental and control group. Then, each group was evaluated using the Wisconsin card sorting test (WCST) and blood test to examine the level of BDNF. Scores on WCST were reported by a group of clinical psychologists fully familiar with the administration of the test, and were then recorded as pretest scores. Blood samples were taken in the morning from fasting participants to check BDNF level. Forty eight hours after the pretest, therapeutic programs were implemented on the experimental group. Motor exercises were performed for 12 weeks (three 45-minute sessions per week). In each session, three types of exercise (each for 10 - 15 minutes) were performed. If any type of exercise proved interesting to students, it was continued for a longer duration. Exercises were arranged from easy to difficult. The therapeutic program for the experimental group included exercises comprising fine (sorting, cutting and sticking colored paper, Frostig exercises, mazes, colored cubes, and targeted exercises including touching the fingers, finger movement, dotting, making a ball, air-drawing a circle, sorting pictures, play-dough, and coloring pictures) and gross (throwing various types of balls: small, large, handball, basketball, volleyball, and tennis, from above, side, down, and back; catching; dribbling; passing the ball between hands; walking on a spiral path while bouncing the ball off the ground for eye-hand-foot coordination, hopping while dribbling the ball, and various jumping skills for body coordination) motor exercises. WCST was administered and blood sampling was performed 48 hours after the end of therapeutic sessions (to eliminate the temporary effects of exercise) for both groups under equal conditions.

3.1. Instruments

Data were collected using the following instruments.

3.1.1. The Child Symptom Inventory (Teacher/Parent Form)

The child symptom inventory is a screening tool for child psychological disorders designed based on the DSM-

III to screen 18 behavioral and emotional disorders in 5 – 12 years old children. Its validity has been reported by various studies to be 0.76 to 0.92 (2).

3.1.2. The Block Test

This test has 7 sections including the following building activities: (1) building a bridge, (2) building a three-piece stair, (3) building a six-piece stair, (4) building a 10-piece stair, (5) connecting parts of the wheel, (6) copying a pattern, and (7) copying the sequence of some blocks. Children's attempt in this seven-item test received a score ranging from 0 (unable to perform any item) to 7 (performing all 7 items). The correlation coefficient of this test was 0.891 in various studies, indicating its high reliability (1).

3.1.3. Wisconsin Card Sorting Test (WCST)

The WCST was developed by grant to evaluate the ability of abstraction and changing cognitive strategies in response to environmental feedbacks. This test is a key indicator of prefrontal lobe activity used to examine executive function. Various scoring schemes have been proposed for this test. In the present study, the most well-known scales have been used, namely:

1- Preservative error: This scale refers to the number of cases in which the test-taker returns to a previous principle while discovering a new one or repeats the previous principle. The reliability of this test is reported to be 0.83 based on inter-rater reliability and 0.85 using the test-retest method on an Iranian sample (1).

2- Total error: Raven's coloured progressive matrices test is the second form of Raven's progressive matrices with 36 pictures most of which are colored, employed to assess the general IQ of children aging 9 to 18 years. Abedi and Rahmani have reported the correlation between this test and the Wechsler intelligence scale for children to be 0.82 showing its reliability. They also reported the validity of 0.87 through the test-retest method (2).

3.1.4. CBC Test

This test is used to examine levels of BDNF. Approximately 5 cc of blood was taken from each participant from the brachial vein. To separate serum, samples were placed in a centrifuge at 3000 rpm for 10 minutes at 4°C.

4. Results

The data were normally distributed based on the significance level of 0.292 to 0.982 using the Kolmogorov-Smirnov test. Table 1 presents the mean age and IQ level of

Table 1. Mean and SD of Age and IQ Level in Children with Dysgraphia

Group	Values ^a
IQ	
Experimental	78.81 ± 3.78
Control	79.19 ± 4.50
Age	
Experimental	10.4 ± 3.5
Control	10.2 ± 3.4

^a Values are expressed as mean ± SD.

Table 2. Descriptive Statistics for Variables in Experimental and Control Groups^a

Group	Pretest	Posttest
BDNF (pg/mL)		
Experimental	542.47 ± 5.083	642.80 ± 21.412
Control	538.31 ± 6.838	538.75 ± 6.933
Preservative error		
Experimental	18.81 ± 2.136	15.50 ± 2.191
Control	17.75 ± 3.416	18.06 ± 1.806
Total error		
Experimental	35.56 ± 2.658	27.13 ± 3.981
Control	35.56 ± 1.825	35.13 ± 1.996

^a Values are expressed as mean ± SD.

children in both groups. Results of the analysis of covariance (ANCOVA) indicated that no significant difference exists between pretest levels of variances across groups (Table 2). Moreover, based on ANCOVA, 12 weeks of regular physical activity significantly increased the serum level of BDNF (Table 3). The f statistic is 397.774 for the effect of the independent variable on the level of BDNF, 31.364 for preservative error, and 48.614 for total error, which is significant at the level of 0.01. In other words, physical exercise increased the level of BDNF while also reducing total error and preservative error in students. Therefore, executive function is improved in these students following physical exercise.

Moreover, results of correlation analysis (Table 4) indicate that, following the physical exercise, the correlation between BDNF is negative with both items of executive function (total and preservative error). Based on the calculated correlation, by increasing the scores of preservative errors, the level of BDNF is decreased, and by reducing the scores of total error and preservative error, the level of this factor is increased.

Based on Table 5, $R = 0.275$ and $R^2 = 0.524$ (coefficient of determination). That is, 52% of the variance of preservative error can be explained by changes in BDNF. Moreover,

Table 3. Results of ANCOVA for Groups

	Ss	df	ms	f	P Value
BDNF (pg/mL)					
Pretest	2945.922	1	2945.922	24.136	0.001
Group	97101.472	2	48550.736	397.744	0.001
Error	5248.416	43	122.056		
Total	105295.81	46			
Preservative error					
Pretest	76.752	1	76.752	32.005	0.001
Group	150.427	2	75.213	31.364	0.001
Error	103.119	43	2.398		
Total	330.298	46			
Total error					
Pretest	15.150	1	15.150	1.479	0.231
Group	995.693	2	497.874	48.614	0.001
Error	350.440	43	10.241		
Total	193.1451	46			

Table 4. Correlation Matrix for BDNF with Preservative and Total Error

	BDNF	Preservative Error	Total Error
BDNF	-		
Preservative error	-0.445	-	
Total error	-0.461	0.561	-

the beta coefficient equals 0.117, showing that the effect of BDNF is negative. Moreover, as the t statistic is significant for preservative error, variations of BDNF affect this variable.

Table 5 shows that $R = 0.629$ and $R^2 = 0.395$. In other words, 39% of the variance in total error can be explained using variations in BDNF. On the other hand, the beta coefficient equals 0.629, indicating that the effect of BDNF is negative. Moreover, as the t statistic is significant for total error, variations of BDNF affect this variable.

5. Discussion

The present study investigated the effect of 12 weeks of motor exercise on the serum level of BDNF and executive function in students with dysgraphia. Based on results, no significant difference exists in pretest levels of variables between experimental and control groups. Moreover, results revealed that a course of motor exercises significantly increased the level of BDNF while also increasing executive function in these children. Studies on the effects of participation in physical education classes and exercise sug-

gest the positive effects of this program on cognitive and motor growth of children and their academic achievement (22). Two mechanisms have been proposed for these effects on motor and cognitive function: physiologic mechanisms such as increased brain blood circulation, structural changes in the central nervous system, and variations in the levels of arousal, as well as learning mechanisms in which physical movement and exercise lead to learning experiences which enhance the cognitive-motor ability (4). Results of the present study are in line with those reported by Lista. Lista examined the effect of motor exercise and education on children's executive function and reported a positive effect. Moreover, Monsell reported the effect of education on executive function in children with SLD. In addition, research suggests that timely diagnosis and intervention affect children's rehabilitation and executive functions. According to Monsell, the use of compensatory methods such as perceptive-motor and psychomotor exercises in addition to other training programs improves educational skills and resolves educational deficiencies. As the promotion of psychomotor exercises forms the basis of growth and is essential, teaching motor skills to children, especially to those with dysgraphia, is critical for various skills (including executive functions). According to Barsh, movement is a variable at work in all types of learning and all children require it. In other words, learning requires movement and occurs only when motor actions, including general body coordination and the balance in small and large muscles, have had a natural growth and

Table 5. Results of Regression Analysis for Preservative Error Based on BDNF^a

Model	Regression Coefficient	SD	Beta	t	P Value
Constant	14.936	1.810	-	8.252	0.001
BDNF	-0.067	0.090	-0.117	-0.754	0.007

^a R = 0.275, R² = 0.524, f = 15.309, sig = 0.007.

Table 6. Results of Regression Analysis for Total Error Based on BDNF^a

Model	Regression Coefficient	SD	Beta	T	P Value
Constant	188.284	53.278		3.534	0.003
BDNF	0.298	0.099	-0.629	-3.025	0.009

^a R = 0.629, R² = 0.395, f = 9.152, sig = 0.009.

are demonstrated by the individual. The use of motor exercises and teaching psychomotor as well as perceptive-motor skills improves the design of sensory-motor skills in child growth, enhancing their sensory-motor systems and perceptive skills, especially the cognitive system. Motor skills can affect cognitive and metacognitive processes. Executive functions are a set of higher-order cognitive processes which assist individuals in planning their activities, organizing them, and regulating their behavior optimally. Therefore, one can state that, due to their potentials, executive functions are of utmost importance in the process of learning, daily life, and academic achievement in children.

Evidence suggests the positive role of motor exercise on the brain and the nervous system. The BDNF is a factor affected by physical exercise and plays a pivotal role in the health of neurons (23). Studies report the increasing effect of running on the treadmill on levels of BDNF, calling this factor as one of the central factors affecting brain plasticity. Moreover, some studies demonstrate the effects of physical activity on cognitive function. Weinman et al. reported that recall and learning were better in exercised animals compared to the inactive group. Furthermore, in animals who had passed the maze test faster, an increased expression of BDNF gene as well as a positive correlation between levels of BDNF and learning have been reported (23). Also, in human studies, a correlation has been found between the level of BDNF and cognitive processes such as memory and executive function.

5.1. Conclusions

A reduction in the level of BDNF in children with intellectual disabilities and SLD as well as the correlation between learning motor skills and levels of BDNF reveal that variations in the level of nerve growth factors, including BDNF, may play a major role in functional and skill variations. These results indicate the effects of motor activities on synaptogenesis in neurons and the realization of these

outcomes in motor function. Thus, based on results of the present study, an increased level of BDNF after a course of physical exercise may play a significant role in improving executive functions in children with dysgraphia. Exposing these children to environmental stimuli (motor exercises) changes the level of BDNF and affects the trend of cognitive processes. Therefore, it seems that motor exercises lead to physiologic adaptations while also increasing the level of BDNF, thus improving memory and executive function in these children.

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