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# Effectiveness of Exercises (Fitness and Aerobic) in the Executive Functions of Problem-Solving Process and Speed of Action in Children with Dyscalculia

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**Abstract**

**Background:** Cognitive rehabilitation and the application of sports exercises is one of the issues that can help improve the performance indicators of children with disabilities.

**Objective:** The present study aimed to determine the effectiveness of exercise (aerobics, aerobics, and fitness) in executive functions of the problem-solving process and speed of action in children with dyscalculia.

**Methods:** This quasi-experimental study was performed based on a pretest-posttest control group design. The statistical population of the study consisted of all male and female students referring to the White Tree Club and the Mentality Psychology Clinic in 2020. Among this population, 24 qualified volunteers were included in the study by convenience sampling method and randomly assigned to two groups of experimental and control (n=12 in each group). Research instruments included the KMat test (Kendall, 1986), the London Tower test (Shalis, 1982), and the Stroop test (1935). Data were analyzed in SPSS software (version 24) using the univariate analysis of covariance at a significance level of 0.05.

**Results:** The results of data analysis demonstrated that after removing the effect of the pre-test, there was a statistically significant difference between the two groups in the mean scores of executive functions of the problem-solving process (P<0.001) and speed of action (P<0.001) in the post-test.

**Conclusion:** As evidenced by the results of this study, it can be concluded that exercise can be used in children with dyscalculia and is effective in improving the executive functions of the problem-solving process and speed of action.

**Keywords:** Dyscalculia, Executive function, Exercise, Mathematics, Memory

## Introduction

Students, as the main pillar of the educational system of the country, have a special role to play in realizing the goals of this system. Therefore, paying attention to the education and physical-mental health of this group leads to the flourishing of the educational system of the society. Students of different ages and educational periods are not the same in terms of learning level, and some of them, especially in the early years of school, lack the abilities acquired by their peers and their behavior compels teachers to introduce them to specialists (1). Although these children act normally and almost the same as their peers in terms of physical development, height, weight, intelligence, speaking, playing, interacting with others, and self-help skills, they have serious problems when they go to school and want to learn to read, write, and count. Learning difficulty is a basic problem in understanding or using spoken or written language, including perceptual disabilities, brain damage, mild brain disorder, dyslexia, speech, reckoning for developmental failure, and dyscalculia (2).

Nowadays, learning disabilities are the largest category of special education, more than half of the students who are identified in normal schools for receiving special education have learning problems. Difficulty learning school lessons is a common feature among children with learning difficulties. One type of learning problem among students is math learning disability (3). Mathematics is considered an important subject for the general public, and this mental activity, which has complex systems of visual, spatial, and geometrical concepts, is very abstract and failure to learn its fundamental concepts and skills is very annoying. Students in schools are always faced with the fear of failure in math learning which sometimes begins from the first year of entering school and never ends. Based on the evidence, 80% of children with a math learning disability have movement disorders, in addition to defects in acquiring the required mathematical problem-solving skills. Moreover, they are presented with serious problems in balance and coordination, which is one of the causes of weakness in balance and coordination, as well as defects in executive functions (4).

On the other hand, executive functions are important structures that play a major role in controlling behavior and are important for successful adaptation and performance in real life. These functions allow people to start and complete assignments and be resistant to challenges, recognize unexpected situations, quickly design appropriate situation maps and programs, manage daily stresses, and prevent inappropriate behaviors (5). Executive functions are a set of excellent abilities, including autonomy, self-initiation, planning, cognitive flexibility, speed of action, working memory, organizing dynamic perception of time, predicting the future, and problem-solving, which help children in daily activities and learning tasks (6).

Based on studies, exercise can resolve many disorders and exerts beneficial effects on executive functions. Aerobic exercises are one of the favorite training methods for children and adolescents. These movements and activities are inherently harmonious and their proper implementation requires regular execution of different movements with specific sequences. Aerobics is a sport performed in the form of law-abiding motion sets that are carried out with planning. Medically, this exercise is an effective means for the prevention of depression and impatience since it results in the release of the endorphin hormone which brings about vitality, concentration, and increased intellectual creativity. Aerobics also enhances nerve and muscle coordination and boosts memory. Fitness exercise stimulates neural tissue and improves motor skills, resulting in improved executive function, which improves cerebellar function and better cognitive development in children (7). In their study, Chaddock-Heyman et al. demonstrated that fitness exercise increases blood flow in children's hippocampus which is related to memory and learning (8).

Aerobic fitness exercise stimulates neural tissue and improves motor skills and executive function, which in turn enhances cerebellar function and better cognitive development in children. This type of practice allows individuals to unconsciously use their mental and artistic creativity and reveal their latent talents. Therefore, repeated failures in students with learning difficulties lead to the belief that they cannot make any progress, adding to the main problem (9). Therefore, the use of therapeutic methods can be of paramount importance in the reduction of learning problems. Exercise is one of the methods used to improve children's learning problems. The interesting point is that the part of the brain that processes movement is the same part that processes learning, surprisingly, in the brain, there's just not a motor center.

Movement and learning have reciprocal and permanent actions, and the part of the brain that is involved in almost all learning (i.e. the cerebellum) is forced to work a lot. On the other hand, motor skills as a method for learning mathematical concepts can be effective in children with mathematical problems since they improve eye-hand coordination, motor sequence of body schema, and information processing. Learning mathematical concepts is enhanced by motor skills, which will be effective in children's performance, promoting learning in mathematical concepts for children with math learning problems (10).

## Objectives

Considering the positive effects of these activities on the physical and mental health of individuals, the present study aimed to investigate the effectiveness of exercise training (aerobic, aerobic, and fitness) in executive functions, such as problem-solving process and speed of action in children with dyscalculia.

## Methods

This quasi-experimental study was conducted based on a pre-test-post-test control group. The statistical population of the study consisted of all male and female students referred to Sepid Tree Club and Mind Psychology Clinic in 2020. Among this population, 24 qualified volunteers were included in the study by convenience sampling method and randomly assigned to two groups of experimental and control (n=12 in each group). The sample size was estimated at 24 subjects (n=12 in each group) by G*Power software (version 3.1) (no need for formula and by specifying the type of statistical tests, the test power was 0.80, the effect size was 0.40, the error level was $\alpha=0.05$). The inclusion criteria were as follows: lack of disability, math learning problems, lack of psychological and neurological problems, studying in normal schools in Tehran, absence of any acute and chronic physical diseases, lack of engagement in other treatment programs at the same time, and non-reception of individual counseling or medication. On the other hand, the exclusion criteria were absence from two sessions and unwillingness to attend the meetings. Ethical considerations in the study were: keeping participants' information confidential and receiving written consent from subjects or their guardians based on their willingness to participate in the study.

## KMAT Math Test (Kendall, 1986)

One of the most important tests ever considered by counselors, testers, and other departments is the KMAT math test, which was prepared by Kennedy in

1985-1986 and revised in 1988 (11). It is used in a restorative program with a special assessment of students' readiness to start education in math courses and provides accurate and sufficient information to teachers for planning and evaluation of educational programs. This test is an individual tool which puts an emphasis on content identification of names (concepts and skills) and organization. This content provides a framework to facilitate the evaluation, diagnosis, and design of education. The test was prepared in 1981, standardized in 1985 and 1986, and finally revised by Kennedy in 1988. The total validity of the test was estimated to be 90%-98% on different bases, and its content and construct validity have been confirmed. In Iran, its reliability and validity in cross-border research were 0.86 and 0.72 (12). In terms of scope and sequence, it consists of three basic concepts of operations and applications that have the same educational importance. These sections are divided into 13 subtests in total. In each section, there are three or four areas that have been selected and bred with relatively equal impulsivity: this test has 258 individual questions that are applied individually. Basic concepts: three subtests of counting, illustrative numbers, and geometry. Field of operation: summing, subtracting, multiplying, dividing, and calculating subjectively, and the field of application: subtests of measurement, time and money, estimation, analysis, and problem-solving.

**Tower of London Test (Shalis, 1982)**

This test was first introduced by Shalis in 1982 in an article entitled "Specific Injuries in Planning and Organization" (13). This test has been developed to measure and evaluate an aspect of executive functions (i.e., planning) (13). The test consists of 14 problems. The items are rated on a scale ranging from 3: the issue is solved in the first attempt, 2: the problem is resolved in the second attempt, 1: the problem is solved in the third attempt, and 0: when three attempts fail. During the test, by moving the colored vertebrae (green, blue, red) and placing them in the right place with the minimum necessary movements, the sample shape should be corrected. It is worth noting that only the upper vertebrae can be moved; moreover, one, two, and three vertebrae are placed in the short, average, and long columns, respectively. The subject is then asked to solve the example and is allowed to solve the problem three times, and the absolute instructions must be solved with the minimum necessary movements of the example. At each stage, after success and if the problem is not resolved after three attempts, the next issue will be given to the respondent. The variables examined in this test, including latency, trial time, total test time (total latency and test time), error count, and total score, are calculated accurately by computer. In this study, the total score was used for analysis. The validity of this test was reported to be 79%; moreover, there was a correlation of r=0.41 between the results of this test and the Porteus Maze test (13). In Iran, the reliability and validity of this test were reported as 0.89 and 0.72, respectively, in a study conducted by Soleimani (14).

**Stroop Test**

It was first designed by Ridley Stroop in 1935 to measure response inhibition ability, selective attention, cognitive variability, and cognitive flexibility (15). The test consists of two stages: the first step is to name the color and the subject is asked to specify the color of the desired shape in a color set at the maximum speed that can be determined by the corresponding key on the keyboard (the circular color is shown in four colors: red, blue, yellow and green on the monitor screen). The aim of this step is only to analyze and recognize the color. The keys are on the keyboard and do not affect the final result.

The second stage which is the main implementation of the Stroop test is called uncoordinated or interfering efforts. In this stage, 48 consonant color words and 48 inconsistent color words of red, blue, yellow, and green colors are displayed to the subject. Consonant words are those with the same color as the word in Persian, while incongruous words are those with colors different from the meaning of the word in Persian; for example, the word green in red, blue, or yellow. A total of 96 consonant and incongruous color words are displayed randomly and sequentially. The subject's task is to determine only its appearance regardless of the meaning of words. The time to deliver each actuator on the display is 2 seconds and the distance between the presentation and the stimulus is 800 milliseconds. Researchers believe that word color assignment (the second experimental phase) measures mental flexibility, interference, and response inhibition. The interference score is obtained by reducing the correct asymmetric number score from the correct consonant number score. The measured indicators in this test are accuracy (number of correct answers) and speed (average reaction time of correct responses against stimulus in thousandths of a second). Ghadiri, Jazayeri, Ashayeri, and Ghazi Tabatabaei reported the reliability of both stages of the test as 0.6 and 0.97, respectively (16). This study made use of the computerized version of the Stroop test, which was prepared by Sina Institute for Behavioral and Cognitive Sciences Research.

To conduct this study, the following steps were taken: firstly, several students with match learning problems were selected and the KMAT questionnaire was administered to them. Thereafter, 24 students who had higher than average scores in the Key Matt questionnaire were selected as those with dyscalculia and randomly assigned to two groups of experimental and control. The experimental group underwent 60-min sessions of group intervention three times a week (totally 42 sessions) for three months (first month: fitness and aerobic exercises, second month: aerobic exercises, third month: aerobic, fitness, and aerobic exercises in combination), while the control group did not receive any intervention. To assess the content validity of the educational sessions, the quality content determination index and the opinion of five relevant university professors were used, yielding a value of 0.99, indicating the appropriate content validity of the intervention program. Before the intervention, the Tests of the Tower of London and the Stroop Test (16) were performed in both groups and readministered one week after the end of the training sessions. A summary of exercise sessions is listed in Table 1.

**Table 1. Summary of exercise sessions**

| First month: fitness and aerobic exercises | |
|---|---|
| **Session** | **Content** |
| **1** | 10-min warm-up. Stretching movements, in situ, rope, squat-foot dumbbell 10×2, launcher with 10×3 dumbbells, back foot single dumbbells on steep table 10×2, underarms Of Plaver Dumbbell 10×2, Dumbbell Armpit Bend 10×2 |
| **2** | 10-min warm-up and tensile movements, dumbbell head 10×2, dumbbell front 10×2, emissions from dumbbells 10×2, front arm dumbbell pair standing 10×2, front arm dumbbell hammer 10×2 |
| **3** | 10-min warm-up and stretching moves, dumbbell chest press 12×2, chest top dumbbell 12×2, Swedish swim on knee 10×2, back arm pair dumbbells sleeping on table 10×2, back arm single dumbbell from overhead 10×2 |
| **4** | 10-min warm-up, Stretching movements, in situ, rope, squat-foot dumbbell 10×2, launcher with 10×3 dumbbells, back foot single dumbbells on steep table 10×2, underarms Of Plaver Dumbbell 10×2, Dumbbell Armpit Bend 10×2 |
| **5** | 10-min warm-up and stretching movements, dumbbell head 10×2, dumbbell front 2×10, emissions from dumbbells 10×2, front arm dumbbell pair standing 10×2, front arm dumbbell hammer 10×2 |
| **6** | 10-min warm-up and stretching moves, dumbbell chest press 12×2, chest top dumbbell 12×2, Swedish swim on knee 10×2, back arm pair dumbbells sleeping on table 10×2, back arm single dumbbell from overhead 10×2 |
| **7** | 10-min warm-up, stretching movements, in situ, rope, squat-foot dumbbell 10×2, launcher with 10×3 dumbbells, back foot single dumbbells on steep table 10×2, underarms Of Plaver Dumbbell 10×2, Dumbbell Armpit Bend 10×2 |
| **8** | 10-min warm-up and stretching movements, dumbbell head 10×2, dumbbell front 2×10, emissions from dumbbells 10×2, front arm dumbbell pair standing 10×2, front arm dumbbell hammer 10×2 |
| **9** | 10-min warm-up and stretching moves, dumbbell chest press 12×2, chest top dumbbell 12×2, Swedish swim on knee 10×2, back arm pair dumbbells sleeping on table 10×2, back arm single dumbbell from overhead 10×2 |
| **10** | 10-min warm-up, stretching movements, in situ, rope, squat-foot dumbbell 10×2, launcher with 10×3 dumbbells, back foot single dumbbells on steep table 10×2, underarms Of Plaver Dumbbell 10×2, Dumbbell Armpit Bend 10×2 |
| **11** | 10-min warm-up and stretching movements, dumbbell head 10×2, dumbbell front 2×10, emissions from dumbbells 10×2, front arm dumbbell pair standing 10×2, front arm dumbbell hammer 10×2 |
| **12** | 10-min warm-up and stretching moves, dumbbell chest press 12×2, chest top dumbbell 12×2, Swedish swim on knee 10×2, back arm pair dumbbells sleeping on table 10×2, back arm single dumbbell from overhead 10×2 |
| **Second month: Aerobic exercises** | |
| **Session** | **Content** |
| **13 to 24** | 10-min warm-up, such as slow and stretching movements, low contact movements such as step in place, knee movement, leg movement, hamstring, Elle biceps, and finally, 5-min cooling down |
| **Third month: Combined fitness, aerobic and aerobic exercises** | |
| **Session** | **Content** |
| **24-42** | The first 10-min stretching exercises for warm-up+50 min aerobic, fitness, and aerobic training combined |

Finally, the obtained data were analyzed in SPSS software (version 24) using analysis of covariance (ANCOVA), Leven's test, the slope of the regression line, Kolmogorov-Smirnov, and T-test at a significant level of 0.05.

## Results

The mean age scores of participants were reported as 9.13±1.24 and 1.03±9.75 years in the experimental and control groups, respectively. To compare the age of the subjects in the two groups, a T-test was used and showed that the difference between the mean age of the studied groups was not statistically significant; therefore, the studied groups were homogenous in terms of age. Table 2 displays the mean pre-test and post-test scores of research variables in experimental and control groups, along with the results of covariance analysis. Before the test, the assumptions of covariance analysis were investigated. The default normality of the data was assessed using the Kolmogorov Smirnov test. Kolmogorov's test was not statistically significant in both variables in the post-test stage and the assumption of normality of the data was established. In addition, another assumption, homogeneity of regression line slopes, was investigated and the results showed that homogeneity of regression line slopes was established for problem-solving and speed variables. Another default, including the same variances, was investigated. The results of Leven's test established the similarity of variances; therefore, the use of a single variable covariance analysis test was not an obstacle.

**Table 2. Mean pre-test and post-test scores of research variables by groups and covariance analysis results**

| Variable | | Group | Pretest | | Post-test | | F | P | Eta |
|---|---|---|---|---|---|---|---|---|---|
| | | | M | SD | M | SD | | | |
| **Executive Functions** | Problem-solving | Experimental | 27.41 | 3.42 | 30.25 | 3.13 | 11.88 | 0.003 | 0.39 |
| | | Control | 26.25 | 2.86 | 25.91 | 3.05 | | | |
| | Speed of action | Experimental | 50.83 | 5.63 | 47.08 | 6.40 | 37.99 | 0.001 | 0.67 |
| | | Control | 54.33 | 4.20 | 55.08 | 4.64 | | | |

As displayed in Table 2, after controlling the effect of pre-test, exercise training had a significant effect on post-test scores of the two experimental and control groups in the planning variable (P=0.003). The effect size was 0.39, signifying that 39% of changes in problem-solving variables were due to the effect of the group. Moreover, after controlling the effect of the pre-test, it was observed that exercise training had a significant effect on post-test scores of both experimental and control groups in the speed of action variable (P=0.001). The effect size was 0.67 which illustrated that 67% of the changes in the speed of action were due to the effect of the group.

## Discussion

The present study aimed to assess the effectiveness of exercise training (aerobic, aerobic, and fitness) in executive functions of the problem-solving process and speed of action in children with dyscalculia. The results pointed out that after the training intervention, exercise training (aerobic, aerobic, and fitness), there was a significant difference between experimental and control groups in executive functions (problem-solving process and speed of action) in children with dyscalculia. Therefore, based on this finding, it can be concluded that exercise training (aerobic, aerobic, and fitness) is effective in the enhancement of executive functions (problem-solving process and speed of action) in children with dyscalculia.

This finding is in line with the results reported by Chaduk et al. who demonstrated that exercise training increased executive functions (8). Moreover, the results of the study were in agreement with those obtained by Van Hooren & Bosch (19), Yigiter (20), and Senduran & Amman (21). In explaining this finding, it can be stated that doing exercises leads to high arousal and optimizes the availability of cognitive resources, and consequently, facilitates learning exercises that require high mental effort and higher speed of action. Increased arousal during exercises results in faster processing of information, possibly due to increased brain concentrations of dopamine and norepinephrine neurotransmitters (17).

In the present study, the used exercises created an "optimal" arousal state and faster processing. The exercise protocols in the present study point to differences in learning practices as a potential source and explain the variations in the study results. Therefore, it can be argued that learning more complex motor exercises is not facilitated by exercises with low and moderate sessions. It is assumed that exercises with more complexity are sensitive to both positive and negative effects since they require more activation of the prefrontal cortex than other exercises. Moreover, the prefrontal cortex is more sensitive to exercise-induced arousal, as compared to other areas of the brain.

Further exercise sessions may increase the brain concentrations of dopamine and norepinephrine neurotransmitters to a degree that creates nervous noise and has a negative effect on the accuracy of training. Nevertheless, when performing exercises, it is not clear what the "optimal" level of neurotransmitter concentrations in the brain is. In addition, more sessions of training require more activation of the motor cortex and complementary motor area. It is believed that these simple exercises will lead to the loss of the active prefrontal cortex and induce weaker cognitive function than complex exercises that require activation of the prefrontal cortex (18). The alternative explanation could be that although these differences in brain activation may jeopardize cognitive processing, increasing motor activation can potentially facilitate motor learning and retention.

Although there are data on motor-training learning, it seems that the overall pattern of results provides the possibility of presenting the following effective hypothesis that exercises with major prerequisites for speed, improvement in cognitive-motor learning, and its maintenance can occur after training with desired intensity and rate (19). On the other hand, as observed in the present research and other studies, motor-cognitive learning and its maintenance in more complex exercises are facilitated by the speed and accuracy required after training with high intensity. Exercise training as a stressor may not affect cognition, as well as motor learning and its maintenance, and depends on training and measuring the results.

Furthermore, in explaining that training exercises (aerobic, aerobic, and fitness) are effective in the improvement of executive functions (problem-solving process) in children with dyscalculia, it can be stated that the cellular processes through which exercises improve the nervous system and cognitive function are not fully known. Nonetheless, human and animal studies have indicated that the cellular process increases brain-derived neurogenesis factor (BDNF) which is the most abundant growth factor in the human brain and is reset in response to exercise (20). There is also some preliminary evidence supporting the role of BDNF as a mediating factor in cognitive enhancements resulting from practice in schizophrenic patients. However, due to the absence of data on other potential mechanisms, the benefits of exercise training in these individuals cannot be attributed only to BDNF (8).

On the other hand, exercise training can significantly improve the process of problem-solving based on cognition. This may be due to increased participation in exercises among individuals or better presentation of the program, leading to more favorable results. It seems that training is a major factor contributing to the increase of the problem-solving process, and among different evaluated areas, cognitive functions have demonstrated the greatest improvement in response to exercise training. Learning disorders have remained constant since the commencement of the disorder and during the period. These disorders are associated with individual and social functioning, as well as life, and cognitive functions more strongly affect real-world performance. Therefore, these effects are encouraging in this area and suggest that cognitive benefits of exercise training can be generalized to improve the cognitive and social functions of these individuals (21).

Among the notable limitations of this study, we can refer to the fact that the participants were restricted to the statistical population of students in Tehran, which limits the possibility of extending the results of this study to other groups. Moreover, due to time constraints and the coronavirus crisis, it was not possible to implement a three-month follow-up period. Based on the limitations of the research, it is suggested that this research be conducted among other communities, and if possible, their data should be compared. It is also recommended that in future studies, a one-to-three-month follow-up be performed to reassess the effectiveness of training. Therefore, it is suggested that exercise training (aerobic, and fitness) be used to improve the problems of children with dyscalculia and improve their cognitive and executive function.

## Conclusion

As evidenced by the results of this study, it can be concluded that exercise training (aerobic, and fitness) can be used in children with dyscalculia and is effective in improving the executive functions of problem-solving and their speed of action.

## Conflicts of Interest

The authors declare that they have no conflict of interest regarding the publication of this article. The participants of this study received a manuscript containing a statement about ethical approval and consent. This article was approved by the ethics committee of Islamic Azad University, Science and Research Branch (IR.IAU.SRB.REC.1399.013).

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