Int. J. School. Health. 2022; 9(4)

Published online 2022 October.

Original Article

Effectiveness of Balance Enhancement Exercises in Improving Dyscalculia and Dysgraphia among Students with Specific Learning Disorder

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Received: July 18, 2022, **Revised:** August 22, 2022, **Accepted:** September 06, 2022

Abstract

Background: Dyscalculia and dysgraphia are among the prevalent problems faced by students with specific learning disorders (SLD). The present study aimed to investigate the role of balance enhancement exercises in improving dyscalculia and dysgraphia among students with SLD.

Methods: This was a quasi-experimental study with a pretest-posttest design and a control group. The statistical population of this study included all boy and girl second-graders and third-graders with SLD who received education and rehabilitation services from public and private centers for learning disabilities in Ahvaz, Iran in 2022. The convenience sampling method was employed to select 30 participants who were equally assigned to experimental and control groups (i.e., 15 per group). The experimental group received balance enhancement exercises (for twelve 45-minute sessions), whereas the control group received no interventions. To collect information, the Dyscalculia Test and Dysgraphia Test were used. The ANCOVA was then used for data analysis.

Results: The mean±standard deviation (SD) of the post-test scores of dyscalculia and dysgraphia in the experimental group was 106.93±14.99 and 75.60±15.10 which was significantly different from the control groups (91.33±14.45 and 60.93±19.36). The results indicated that balance enhancement exercises improved dyscalculia and dysgraphia in students with SLD ($P<0.001$).

Conclusion: According to the results, balance enhancement exercises can be employed to boost academic achievement by improving dyscalculia and dysgraphia in students with SLD.

Keywords: Specific learning disorder, Dyscalculia, Agraphia, Students

How to Cite: Changizi T, Naderi F, Homaei R, Bavi S. Effectiveness of Balance Enhancement Exercises in Improving Dyscalculia and Dysgraphia among Students with Specific Learning Disorder. Int. J. School. Health. 2022;9(4):257-263. doi: 10.30476/INTJSH.2022.97016.1264.

1. Introduction

Specific learning disorder (SLD) refers to a condition in which a student's academic achievement is lower than expected concerning age, IQ, and tests for reading, writing, and calculation (1). Emerging in the absence of mental disabilities, neurological dysfunction, or environmental deprivation, this disorder usually manifests itself in the early years of school (2, 3). As a result, students experience difficulties in reading, comprehension, written expression, spelling, and mathematics (4, 5). This disorder's prevalence has been reported at 4.5–7% in Iran (6). Students with SLD often experience cognitive problems, especially in attention, memory, perception, processing speed, planning, problem-solving, thinking, and cognitive flexibility (7).

Dyscalculia is among the most prevalent and most important SLDs in students. Nearly 5–8% of schoolchildren have difficulty in learning mathematics (8). Dyscalculia is a mathematical disorder that disrupts the abilities to learn numerical concepts, perform accurate calculations, and solve problems and other major mathematics skills. People with dyscalculia experience problems in all fields of mathematics. The lack of proper education, mental disability, or other conditions do not explain their problems. Dyscalculia affects daily aspects of life, including the complicated concepts of mathematics, such as telling the time, counting money, and doing mental calculations. Moreover, dyscalculia is usually comorbid with dyslexia (9).

Dysgraphia is another case of SLD in students. Most students with dyslexia have difficulty in writing and spelling (10). Dysgraphia affects other educational activities of the child at the beginning of school and jeopardizes both occupational and social achievements. Writing skills depend on other skills such as correct understanding of words, legible handwriting, and grammar. Major

problems in writing are classified as illegible handwriting, misspelling, and bad composition writing (11). Writing involves complicated visual perceptive and motor skills. It is mediated by attention, perception, memory, motion, and executive functions, coordinated and integrated at different levels to produce a word. Visual motor skills include a set of coordination between visual information and motor plans that are important in handwriting development. Therefore, students with dysgraphia should be provided with motor planning, eye-hand coordination, visual perception, motor perception, subtle motor control, attention, concentration, and dexterity skills (12, 13). Researchers have evaluated the relationships between visual motor skills, perceptive skills, and handwriting to analyze each component of handwriting partially. According to their results, only the visual motor components predicted the superior success of written expression (14).

Different studies have discussed the presence of balance motor dysfunctions among students with SLD (15, 16). Rochelle and Talcott (16) reported that more than 70% of SLD cases have motor dysfunctions. According to the research evidence, nearly half of the students with dyscalculia and dysgraphia experience difficulty in balance and motor coordination. Their vestibular systems and cerebella are involved. Balance dysfunctions in students with SLD are caused by sensory integrity flaws and cerebellar development disorders (1, 17). Given the extensive traumas and complications of dyscalculia and dysgraphia, different models have been employed to treat these disorders. Researchers have proposed cognitive, behavioral, pharmaceutical, combinatorial, and supplementary treatments to deal with various problems faced by students with dysgraphia. Given the effects of motor dysfunctions on other aspects of life in dysgraphia cases, a sensorimotor integrity treatment has recently attracted researchers (18). Motor stimuli include different sources and types of energy that can cause the potential for action in sensory receptors, such as auditory perception, visual perception, somatosensory system, and vestibular system. Finally, the person or the brain is aware of a stimulated receptor and shows an appropriate reaction (19).

Flaws in sensorimotor functions are among the complications faced by students with SLD. Sensorimotor functions depend on sensory systems used by living creatures as the sources of information obtained from the surrounding environment, giving the proper response and successful compatibility with environmental needs. In human beings, the sensory system provides some pathways for the brain to receive information, interpret stimuli, and give a response (20). Proprioception is the most important sensory channel in developing basic senses. People use the information obtained from proprioception to coordinate their bodies, balance, and motor skills (1320) indicated that sensory integrity would improve dysgraphia in students with SLD. Mahvash-Vernosfaderani and colleagues (21) reported that sensorimotor integrity affected students' balance performance and reading skills with dysgraphia.

In general, attention and concentration on basic senses and integration of these senses with the second-level senses will lead to coordinated processing and provide the conditions for learning reading and writing. Dyscalculia and dysgraphia are significant problems for students with learning disabilities. Among the seven senses, balance is essential in students' ability to write and do mathematics. Accordingly, the present study aimed to investigate the role of balance enhancement exercises in improving dyscalculia and dysgraphia among students with SLD.

2. Methods

This was a semi-experimental study which had a pre-test-post-test design and conducted with a control group. The statistical population of this research included all second and third-grade boy and girl students with SLD who received educational and rehabilitation services from government and private centers for learning disabilities in Ahvaz, Iran in 2022. The inclusion criteria were consent from parents of the students for participation in the research, symptoms of dyscalculia and dysgraphia in students, and no symptoms of autism, mental retardation, intelligence disorders, and other psychological disorders. Moreover, the exclusion criteria were lack of parental consent for students' participation in research, concurrency of pharmacotherapy, and more than two sessions of absence in the intervention. The convenience sampling method selected 30 eligible participants as the research sample. The sample size was selected based on G-Power software with a significance

level of 0.05 and a test power of 0.8. The mean±SD of the main variable in the experimental and control groups were 106.93±14.99 and 91.33±14.45, respectively, which indicated the adequacy of the sample size based on previous research (22). They were then randomly assigned into an experimental group of balance enhancement exercises (15 participants) and a control group (15 participants). The research sample was assigned into the experimental and control groups using random numbers table; So that even numbers were considered for the experimental group and odd numbers were considered for the control group. The researcher, who had attended treatment courses and specialized workshops in groups, implemented the treatment. For compliance with ethical principles, sessions of balance enhancement exercises were briefly implemented in the control group after training sessions, and the posttest was finished in both the experimental and control groups.

2.1.Research Tools

Dyscalculia Test: The KeyMath test was conducted to analyze dyscalculia. Designed by Connolly (23), this questionnaire was used extensively to identify students with problems in mathematics. This test consists of 13 subscales in three areas of operations, concepts, and applications. Each area includes some subtests, each of which has several items that together evaluate specific concepts. The area of concepts included the subtests of counting, rational numbers, and geometry. The area of operations included the subtests of addition, subtraction, multiplication, division, and mental calculation. Finally, the area of applications included the subtests of items regarding measurement, time, money, estimation, interpretation, and problem-solving. This test has 258 questions. A score of 1 was given for correct answers, and a score of zero was given for wrong answers. Therefore, the range of scores in this test is between 0 and 258. A high score on this test denotes a declined level of dyscalculia. Eight experts evaluated the questions of the Persian version of the dyscalculia test, and the Content Validity Index (CVI) and Content Validity Ratio (CVR) were reported as 0.90 and 0.98, respectively (24). Jafari (25) reported an alpha Cronbach coefficient of 0.84 for the tool.

Dysgraphia Test: The test of diagnostic dictation disorders was employed to measure dysgraphia. The dysgraphia test has ten subtests as follows: word writing, synonyms and antonyms of words, sentence writing, true and false sentences, writing descriptions of pictures, completing the sentences, completion of writing, plural and singular, changing the sentences, and the main meaning of the sentences. The dysgraphia test has 310 questions. For correct answers, a score of 1 and zero for wrong answers was considered. The range of scores in this test is between 0 and 310. Jabbari (26) normalized this test on 2403 elementary schools (third, fourth, fifth, and sixth grades) and reported that the dysgraphia test had good quantitative validity (CVI=0.96, and CVR=0.91). The authors reported an alpha Cronbach coefficient of 0.93 for the tool (26).

2.2. Intervention Program

Balance enhancement exercises: Bruininks–Oseretsky Test of Motor Proficiency (27) was conducted in twelve 45-minute sessions twice a week. A summary of the balance enhancement exercise sessions is presented in Table 1.

2.3. Statistical Analyses

The descriptive statistics (i.e., mean and standard deviation) and the inferential statistics indices (i.e., ANCOVA) were employed to analyze the data obtained from the pretest and posttest steps. Paired t-test was used for within-group comparison.

3. Results

The participants included 30 boys and girls students with SLD with an average age of 7.79±1.32 years. The mean and standard deviation (SD) of the age of the participants in the experimental and control groups were 8.23±1.10 and 7.04±1.12, respectively. Six (40.0%) participants in the experimental group were girls, and 9 (60.0%) were boys. In the control group, 7 (46.7%) participants were girls, and 8 (53.3%) were boys. Table 2 denotes the means and standard deviations of research variables from the experimental and control groups in the pretest and posttest.

Before the analysis of hypothesis data, the research hypotheses were analyzed to ensure that the research data would estimate the ANCOVA hypotheses. For this purpose, the normality of data through the insignificance of Kolmogorov–Smirnov Z indicated that dyscalculia (Z=0.171; P=0.200) and dysgraphia (Z=0.193; P=0.137) followed a normal distribution.

Table 1: A summary of the balance enhancement exercises

Sessions	Balance enhancement exercises
1	Becoming acquainted with parents and students; evaluating the implementation of Bruininks–Oseretsky Test of Motor Proficiency
2	Standing on balance board in different positions; standing on one foot with eyes open and closed for 20 seconds; hazelnut-breaking balance game
3	Spinning; doing trampoline exercises; stepping on a ladder (10 exercises)
4	Maintaining balance; pushing; running through barriers spirally
5	Throwing a ball from a 3-meter distance; double-hopping; hazelnut breaking
6	Maintaining balance on a rolling board; jumping and turning 180°; rope-walking balance game
7	Maintaining the balance of a stick; placing a student in a large tire and moving it in different directions
8	Standing on a large balance board and maintaining balance; pushing activity; time-to-clean balance game
9	Placing a student in large tire and moving it in different directions
10	Throwing a ball from a 3-meter distance; maintaining balance on one foot; playing balance hopscotch; playing with a scooter board
11	Standing on one foot with eyes open and closed for 20 seconds; jumping up and down on a therapy ball
12	Doing the barrel activity (17 exercises); doing the footstep activity; plastic loops; game of jumping and spinning

Table 2: Mean and standard deviation (SD) of research variable in experimental and control groups

Variables	Groups	Pretest	Posttest	P (within-group)
		Mean±SD	Mean±SD	
Dyscalculia	Balance enhancement exercises	91.46±17.65	106.93±14.99	0.015
	Control	93.40±15.08	91.33±14.45	0.704
P (between-group)		0.749	0.007	-
Dysgraphia	Balance enhancement exercises	58.90±17.24	75.60±15.10	0.008
	Control	62.10±19.86	60.93±19.36	0.871
P (between-group)		0.641	0.028	-

Furthermore, Levene's test was conducted to analyze the homogeneity of variances (and to ensure the sameness of variances in the experimental group and the control group) for dyscalculia (F=1.714; P=0.433) and dysgraphia (F=0.426; P=0.519).

According to the results, the ANCOVA can be used. Therefore, the multivariate ANCOVA was employed to compare the experimental and control groups based on the posttest scores after the pretest effects were controlled to determine the impact of balance enhancement exercises on dyscalculia and dysgraphia in students with SLD. The multivariate ANCOVA results indicated that the two groups were differed significantly regarding at least one dependent variable (P<0.001). According to the results of univariate ANCOVA, the F-score of the univariate ANCOVA for dependent variables indicated significant differences between the experimental group and the control group in terms of dyscalculia and dysgraphia (P<0.001). In other words, balance enhancement exercises alleviated dyscalculia and dysgraphia in students with SLD. Comparing the mean of dyscalculia and dysgraphia scores between the two groups in the pretest and post-test are presented in Figure 1.

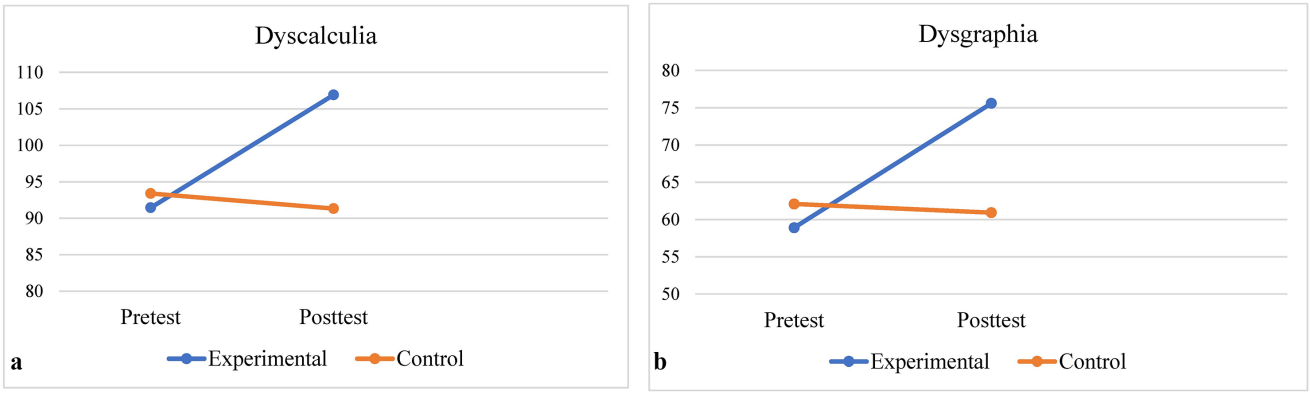

Figure 1: The figure shows the comparison of the mean dyscalculia (a) and dysgraphia (b) scores between the two groups in the pretest and post-test.

4. Discussion

The present study aimed to investigate the role of balance enhancement exercises in improving dyscalculia and dysgraphia among students with SLD. The results indicated that balance enhancement exercises improved dyscalculia. This finding was consistent with the results reported by Naderi and colleagues (28), analyzing the effectiveness of motor perception training in improving reading, writing, and mathematics in students with SLD, and those reported by Ahmady (29) investigating the efficacy of motor perception training in enhancing motor skills and mathematical skills in autistic children. To explain this finding, it can be stated that successful motor perception depends on cortical activities and interactions between spontaneous brain activities and the activities of stimuli in the sensory cortex (28). Training motor perception through the stimulation of spontaneous brain activities and activities of nerve cells can develop new synapses and initiate normal cognitive activities in students with dyscalculia and increase their visual perceptive motor sensitivity. At the same time, the theories of motor control and motor learning state that interactions of the basal ganglia, cerebellum, and frontal lobe are involved in disorders with visual perception failures. However, motor perception can affect these areas because this training is a unique activity that needs to receive information from the visual system related to object detection and location determination in the space. It is also closely linked to motor perception (29). The proponents of motor perception believe that motor learning is the first step in learning other activities and that superior mental processes are performed after appropriate transformations are made in motor and perception systems and establishing motor–perception links.

According to the results, balance enhancement exercises improved dysgraphia in students with SLD. This finding is consistent with the research results of previous studies (20, 21). In general, the results indicated that instructing students with SLD in balance enhancement exercises enhanced their sense of balance. Balance enhancement exercises are correlated with changes in muscular power, motor function, and positional proprioception in students with poor levels of physical awareness and diagnosis of coordination disorders. Balance enhancement exercises improved the coordination of senses, mitigated the symptoms of dysgraphia, and enhanced the sensory profile. Although a few studies have been conducted on dysgraphia, they classified organization, learning rate, attention, exploratory behavior, biological rhythm, sensory responsiveness, game skills, self-esteem, respective interaction, and familial compatibility as the areas that might change in response to the sensory integrity treatment. Furthermore, any motor coordination training through different principles and theories can affect written expression (20).

Written expression problems emerge from environmental factors such as inappropriate pens, inappropriate surfaces for writing, and inappropriate body positives while writing. They can also be caused by internal factors referring to the intrinsic abilities of students, such as visual motor coordination, motor planning, subtle motion control, and appropriate manipulation of writing tools in hands. Boys and girls may differ in these abilities. Compared with normal children, those with these disorders experience too many misspellings, add or delete letters, and correct further letters. They also write too large letters. The main concern with diversity lies in writing letters because children manifest diversity in the heights of letters, distances between letters, distances between words, and balance of letters on the baseline. In addition, the diversity problem is exacerbated when longer texts are to be written; it indicates that these children have further difficulties in written expression within longer periods (20). In the early years of school, the legibility of written expression was correlated with perceptive visual abilities, poor eye-hand coordination, and behavioral problem among these students. However, dexterity and finger detection skills (e.g., sensory awareness) are related to the written expression rate in students. It is necessary to emphasize techniques of handwriting enhancement and rehabilitation techniques. Therefore, the correct perception of mechanisms and factors that can cause handwriting difficulties and implementation of early therapeutic interventions seem essential before complications are exacerbated (21).

4.1. Limitations

There were some limiations in the study including lack of control over families' educational, economic, and social levels, limited generalization of results to higher grades, and limitedness to the grades and ages of participants in the sample.

Since the statistical population included only the students with SLD in Ahvaz, precautionary measures should be taken before the results are generalized to students from other cities. The proposed intervention is recommended to be implemented in family training classes and other groups of students with special needs. It is also advisable to employ a more significant number of participants. In future studies, it is suggested that the research variables be investigated in boys and girls separately. To analyze the stationarity of results, it is recommended to implement follow-up steps in future studies.

5. Conclusions

In general, the results of this study indicated that balance enhancement exercises alleviated problems of dyscalculia and dysgraphia in students with SLD. Balance enhancement exercises were designed to meet the learning needs of students with SLD. These exercises included motor exercises and competitive and exciting games that would encourage students to continue the training sessions and maintain the motor effects. As a result, balance enhancement exercises facilitated the functions of writing and doing mathematics. Therefore, purposively organized and controlled balance enhancement exercises can be used as an alternative technique for improving the functions of writing and doing mathematics in students with SLD.

Acknowledgement

The researchers wish to thank all students and teachers in Ahvaz who have helped us in preparing this study.

Ethical Approval

The Ethics Review Board of Islamic Azad University, Ahvaz branch, approved the present study with the code of IR.IAU.AHVAZ.REC.1400.079. Also, written informed consent was obtained from the pariticpants.

Conflict of Interest: None declared.

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