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The effectiveness of neurofeedback on the management of academic performance in students with academic failure: experimental research

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Background: The present study aimed to study the impact of neurofeedback on the academic performance of nursing students with academic failure.

Methods: This study was an experimental one with a pretest–posttest design with a control group. The statistical population of this research was the nursing students of the Faculty of Nursing, Tehran University of Medical Sciences University of Medical Sciences. The sample of this study consisted of 60 individuals chosen by a simple random sampling method and two experiment groups ($N=30$) and a control group ($N=30$) were replaced by accident. Neurofeedback was an advanced Raven test and a researcher-made questionnaire for data collection. Thereafter, the experimental group was treated with neurofeedback for 7–10 weeks and 20 50-min therapeutic sessions as the experimental condition. In the first 130 s, the baseline was determined for the individual, and during the session, the baseline was practiced. Each session consisted of six exercises, each lasting 7 min.

Results: The results of the covariance analysis showed that students who had an educational drop and were trained in neurofeedback sessions showed a significant increase in the next half ($P<0.05$) compared to the control group.

Conclusion: The results of this study showed that neurofeedback is an effective method for managing the academic performance of nursing students with academic failure.

Keywords: academic failure, academic performance, neurofeedback, nursing students

Introduction

Governments and communities see education as a necessity to reduce global poverty and increase equality, peace, and sustainability for all[1]. Efficient and effective human resources training is one of the main tasks of universities and since students of high capital are talented, innovative, and resourceful, their attention is very important. Student dropout is one of the major problems in higher education centers in the country. There are various definitions and definitions of academic failure, all of which have in common the inability and failure to complete formal education[2]. UNESCO (United Nations Educational, Scientific and Cultural Organization) attributes the concept of academic failure to baseline repetition, early dropouts, and a decline in educational quality. Academic failure includes various aspects of academic failure, such as repeated absence from the university, early school leaving, repetition of schooling, poor quality of education, and access to information rather than information[3]. Studies show that this problem is increasing every year and many students are unable to complete or deliver educational content on time[4]. Studies show that about 12% of college students are suspended for at least one semester during their studies, which puts them at risk of being excluded[5].

HIGHLIGHTS

- Neurofeedback can help students with learning disabilities regulate their brain wave activity and since the self-regulating mechanism of brain waves plays a fundamental role in the design and normal functioning of the brain. Therefore, the improvement of attention and memory deficits can explain the improvement in academic performance.
- A student's academic failure is due to various factors and it is necessary to analyze various variables that may reduce the effectiveness of neurofeedback over time.
- Increasing the length of neurofeedback training sessions in combination with other methods may also improve student performance.

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Student dropout is not only an individual problem but also a major social problem with consequences for the community. Students who drop out of school are more at risk of crime, substance abuse, physical and sexual abuse, and ultimately family and mental disorders[6]. A study conducted at one of the USA universities found that students' most important cause of suicide was an academic failure[7].

In this study, neurofeedback was used as a therapeutic approach to address students' academic problems. Neurofeedback is an agent-conditioning process so that one can learn to alter the electrical activity of the brain[8]. The mechanism of neurofeedback effects on academic performance refers to the modification of the psychological processes of individuals seeking therapeutic sessions, so that psychological processes such as learners' attention and memory of the subject matter are central factors in teaching and learning, as Bandura emphasizes. Slowly, the initial phase of any learning begins with attention, and if attention is not sufficient, one's learning is impaired[9]. Attention-deficit disorder is one of the core learning and learning problems[10–14].

On the other hand, studies have shown that the highest frequency of electroencephalography (EEG) abnormalities in people with attention and memory problems, increased theta activity (4–7 Hz) and long beta (22–30 Hz), and decreased beta activity (13–21 Hz) in central regions and forehead[15]. These facts indicate that correcting EEG abnormalities by performing individual neurofeedback sessions leads to improved attentional processes[16–18]. Over the past three decades, many studies of neurofeedback therapy have shown that this strategy addresses a wide range of issues such as depression and anxiety, attention-deficit/hyperactivity disorder (ADHD), learning disorders, optimal healthy performance and improvement of personality traits, academic achievement, and cognitive abilities[19–22]. Studies on students are very limited. Nan *et al.*[23] showed in a study of normal students that neurofeedback training increased their attention. Orlando and Rivera[24] showed that neurofeedback significantly increased verbal intelligence and overall intelligence in students with learning problems but was not significant in practical intelligence. Gholizadeh[25], in a study on the effect of neurofeedback training on visual memory, showed that after 20 sessions of neurofeedback training, the experimental group showed significant improvement in visual memory.

Considering the inadequacy of the current methods in reducing the academic problems of students and considering the limitations of studies in the field of using the neurofeedback method in reducing academic problems, this area can still be investigated. Therefore, the study aims to investigate the effectiveness of neurofeedback in managing the academic performance of nursing students with academic failure.

Method

This study is an experimental one with a pretest–posttest design with a control group to evaluate the effectiveness of neurofeedback training. The descriptive method was used for data processing at central tendency, dispersion, abundance, and percent indices.

Population and samples

The statistical population of this research was the nursing students of the Faculty of Nursing, Tehran University of Medical Sciences University of Medical Sciences, in 2022 with a grade point average lower than 12 ($N = 400$).

A sample of 300 students was selected randomly from among students with academic failure and using a neurofeedback device, neglect index, that is theta to the beta ratio in four positions (no activity, reading a text, drawing a shape, and listening to a talk) in the CZ area was evaluated by assembling a single channel and a reference (one polar) and identifying students with a 2:1 ratio and above ($n = 78$). Then, 60 subjects were selected by simple random sampling and 30 were randomly assigned to the experimental group and 30 to the control group. Also, sample size selection ($n = 40$) was carried out according to the experimental study method so that the sample size would suffice for at least 15 individuals per experimental group, Singh and Masuku[26]. But according to factors such as the drop in the number of subjects is considered 20 persons for each subgroup. Five experimental groups (due to not attending and completing the sessions) and two control groups (one due to dropout and one transitional) were excluded from the list, with a total of 33 results were analyzed. Their age range was 18–25 years, with a mean of 20.06 and a standard deviation of 1.99.

Tools

Neurofeedback device

The model used in this study is a 10-channel battery-operated system. Once installed, the software can be run with the help of a computer system. It uses electrodes that connect to the body to provide people with information about some of the biological functions of their bodies[27]. The device works in such a way that electrodes are treated with special glue on the ear's scalp and ear, according to the International System of Therapy 10–20. Then, with the aid of computer equipment, based on the individual brainwave amplitude (measured in microvolts), visual or auditory feedback (usually in the form of a game, image, or computer audio) is provided to the individual. One finds in higher stages that he can control and regulate this feedback using his brain waves. The continuation of this process causes changes in the status of the brain waves, and their abnormalities are improved[28]. This device was used in the present study to implement the therapeutic protocol.

Advanced Raven Progressive Matrices test

Raven's Progressive Matrices IQ is a valid IQ test that has acceptable reliability and validity to measure the overall factor. The advanced form of this test is a useful tool for assessing the intelligence of bright and prominent individuals (students) and students. In a study of 707 students studying at Khorasgan Islamic Azad University, Vafa *et al.* showed that advanced Raven's Progressive Matrices test to measure students' general intelligence had significant reliability and validity ($P < 0.01$). Using the standard scores calculation method, weights equations were obtained on the Wechsler Intelligence Scale with a mean of 100 and a standard deviation of 15. There was no significant difference between the mean scores of boys and girls in this test ($P < 0.01$). A comparison of the mean scores of the raw scores of subjects at different ages showed that there was no significant difference between the mean scores after 18 years of age[29,30].

Researcher-made questionnaire demographic characteristics

The researcher-made questionnaire included questions that asked students individually, such as age, marital status, entrance, field of study, place of residence, probation, and grade point average. It should be noted that the frequency of students' probation and grade point average was extracted from their academic records in college education.

Method of treatment sessions

After identifying and selecting students, the tests defined in the present study were performed and then were randomly divided into two groups (experimental and control). Thereafter, the experimental group was treated with neurofeedback for 7–10 weeks and 20 50-min therapeutic sessions as the experimental condition. In the first 130 s, the baseline was determined for the individual, and during the session, the baseline was practiced. Each session consisted of six exercises, each lasting 7 min. There was a 30-s rest between exercises. Students received both visual and auditory feedback. In the first session, the connection between the neurofeedback device, the student body, the computer, and the screen was described. Students were instructed to play games successfully with the help of thoughts, calmness, and focus on the display and assignments. The electrodes were connected to the head by the International 10–20 system, in which a single channel was polarized, a blue electrode was at the CZ site, and two yellow and gray electrodes were connected to the ears. The location of the electrodes and target waves were determined based on previous studies, so that in the first half of treatment, the CZ band Beta 15–15 Hz was the additive band, and theta bands (4–7 Hz) and beta bands (22–30 Hz) were selected as suppression bands and in the second half of treatment; in the CZ region of the sensory-motor band 15, 12 Hz was used as an increasing band and theta bands (4–7 Hz) and beta bands (22–30 Hz) were used as suppression bands. As a result, a person was given a score that could set the incremental wave above the threshold for a half-second and keep the descending wave below the threshold. This score was given to the subject in visual (on the selected game page), score (recorded on the computer page), and audio feedback. This process continued until the end of the session. The control group was engaged in routine activities during this time. After the sessions, the groups were re-tested, and then the preliminary results of this study were presented to them[31,32].

Data analysis

To analyze the data, descriptive statistics methods such as central tendency and dispersion indices were used to describe the distribution of variables, and at an inferential level, analysis of covariance (ANCOVA) was used to test statistical assumptions. For this purpose, SPSS-25 software was used.

Results

To evaluate the effect of neurofeedback on the academic performance of students with academic failure, students' scores in the pretest and posttest stages were compared in two experimental and control groups.

According to Table 1, the demographic findings of the study showed that 90% were single and 10% were married, 31.7% were native, and 68.3% were non-native. 33.3% stated that their interest in the field was low, 45% medium, and 21.7% high.

Table 1

Demographic characteristics of people participating in the study.

Variables	Groups	*F*	%
Gender	Female	43	71.7
	Male	17	28.3
Marital status	Single	54	90
	Married	6	10
Interest in the field of study	Low	20	33.3
	Medium	27	45
	High	13	21.7
Residence	Native	19	31.7
	Non-native	41	68.3

According to the information in Table 2, it is observed that the mean score of the half-year students in the experimental group was 11.02 on the pretest and 12.83 on the posttest. The experimental group and 11/98 were obtained for the control group. Comparison of pretest and posttest showed the effect of the independent variable of neurofeedback training on increasing semester grade point average in comparison with the previous semester's grade point average in experimental group students. No such difference was observed in the control group averages.

Before analyzing the results and reporting the covariance analysis, observations of the assumptions of this analysis are reported in Table 2.

As Table 3 shows, the assumption of homogeneity of slopes with $F = 2.15$ (29 and 1) is not significant for grade point average (GPA), so the lack of interaction indicates that the data support the homogeneity hypothesis of regression. Also, the approximation of the regression slopes was approximately parallel to the confirmation of the 'homogeneity of regression assumption', and there was a linear relationship between the random auxiliary variable and the dependent variable. R^2 also indicates the correlation between the dependent variable and the random variable. The nonsignificance of Levon's test also indicates that the variance equation error condition is met. Therefore, considering the assumptions of covariance analysis, we compare the experimental and control groups.

As shown in Table 4, the results of the analysis of covariance show that in the mean variable, after adjusting the IQ scores of the two experimental and control groups ($F = 5.18$ and $P < 0.03$), the mean scores of the group experimental in GPA with $F = 4.34$ was more than the control group at $P < 0.05$ and $E = 0.13$. Therefore, the results showed that students with academic failure who were trained in neurofeedback sessions had a higher average score than students who did not attend neurofeedback sessions.

Table 2

Mean and SD of the semiannual average in the experimental group and the control group.

		Pretest	Posttest	Adjusted posttest
Variable	Group	Mean ± SD	Mean ± SD	Mean ± SD
GPA	Experiment	11.02 ± 0.68	12.83 ± 0.97	12.75 ± 0.27
	Control	11.90 ± 0.61	11.92 ± 1.20	11.98 ± 0.24

GPA, grade point average.

Table 3

Test results assumption of slope homogeneity.

Source	SS	df error (total)	MS	*F*	Significance	R^2	Levene's test, *F* (significance)
Group	1.93	29 (33)	1.93	1.77	0.19	0.06	(0.082) 3.23
Pretest	3.89	29 (33)	3.89	3.56	0.07	0.11	
Group × Pretest	2.34	29 (33)	2.34	2.15	0.15	0.07	

df, degrees of freedom; MS, mean square; SS, sum of squares.

Discussion

The results of covariance analysis showed that students with academic failure and who were trained in neurofeedback sessions reported a higher average score in the following semester compared to students who did not attend neurofeedback sessions.

Consistent with this research, many studies have demonstrated the impact of neurofeedback on individuals' performance[33–36].

To explain this finding, the human brain is capable of modifying itself, that is, the ability to learn or re-learn the self-regulating mechanisms of brain waves that are central to the brain's natural design and function[37]. So neurofeedback training is a reinforcement of the self-regulatory mechanisms required for effective functioning. This training system encourages the brain to modify, modulate, and maintain proper activity by giving the brain feedback on what the individual has been doing in the past few seconds and what the brain's natural bioelectric rhythms were. As a result, the brain is required to manipulate different brain waves by producing more of some waves and producing less of others[38]. The underlying mechanism of this change may be explained by factor conditioning theory if the precontracted stimulus shift (brainwave amplitude) is accompanied by a desirable outcome (motion of video images or sound production) leading to amplification. Learning will occur and this learning will be more effective when it uses simpler stimuli (such as neurofeedback training) that lead to reinforcement. On the other hand, the therapeutic protocol used in this study is important. Studies have shown that an increase in slow brain waves (less than 10 Hz) in different brain regions is associated with foggy thinking, slow response time, arithmetic failure, poor judgment, impulsive control, and decreased attention and arousal in individuals. A high beta (20–30 Hz) fast waves are associated with excitement, excitement, anxiety, and rumination. The centerpiece of these two is beta (13–21 Hz), which is associated with centralization, analysis, relaxation in guided thinking, reduced interference of irrelevant stimulus processing, and facilitation of cognitive integration of task-related stimuli[39]. Therefore, it is expected that by reducing or suppressing the amplitude of theta (4–8 Hz) and long beta (22–30 Hz) and increasing beta (15–18 Hz) and sensory motor rhythm (SMR) (12–15 Hz) in the CZ region, the behavior changes. In particular, there was an increase in attention and attention in individuals.

Table 4

ANCOVA covariance analysis results for mean intelligence and posttest scores of experimental and control groups at half-year average.

Variable	Source	SS	df	MS	*F*	Significance	ES
GPA	IQ	5.60	1	5.60	5.18	0.03	0.14
	Group	4.69	1	4.69	4.34	0.04	0.13
	Error	32.41	30	1.08			

df, degrees of freedom; ES, effect size; GPA, grade point average; MS, mean square; SS, sum of squares.

Conclusion

It can be concluded that neurofeedback can help students with academic failure in regulating brain wave activity and since the self-regulating mechanism of brain waves plays an essential role in the design and normal functioning of the brain. Therefore, with the help of neurofeedback, it is possible to help regulate brain waves and improve the academic performance of students with academic failure. In sum, it should be remembered that student dropout is due to various factors and it is necessary to analyze various variables that may reduce neurofeedback effectiveness over time. Increasing the length of neurofeedback training sessions in combination with other methods may also improve students' performance.

Limitations and suggestions

This research, like other research, had limitations that are hoped to be resolved in future studies. One of these limitations was that in this research, there was no intervention in the control group, and the lack of a sufficient sample of students from other fields and universities prevented the generalization of these results to students from other fields and universities. Also, the internal research that has been conducted so far regarding the effectiveness of neurofeedback on various disorders, such as depression, anxiety, hyperactivity, etc., has only focused on the effectiveness of neurofeedback in improving the symptoms of disorders and has not paid attention to academic performance and academic failure. This is the first time in Iran that we have studied the effect of neurofeedback on these variables.

It is suggested to compare neurofeedback treatment with other treatment methods to reduce academic failure and manage academic performance in future research. Also, considering the importance of neurofeedback and its role in improving academic performance, it is suggested to use neurofeedback training to improve the academic performance of all students, other people, and different age groups.

Ethical approval

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All procedures involving human subjects/patients were approved by Research Ethics Committees of Islamic Azad University – Boroujerd Branch (Ethical code: IR.IAU.B.REC.1401.034).

Consent for publication

The authors ensure that the changes have not distorted the scientific meaning.

Patient consent

Informed consent was obtained from the participants.

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There were no financial sponsors for this study.

Author contribution

Z.K. and M.M.S.: conceived and designed the evaluation and drafted the manuscript; Y.M., H.B., and S.M.H.: participated in designing the evaluation, performed parts of the statistical analysis, and helped to draft the manuscript; M.S. and F.R.K.: re-evaluated the clinical data, revised the manuscript and performed the statistical analysis, and revised the manuscript; S.N. and Z.K.: collected the clinical data, interpreted them, and revised the manuscript; M.M.S. and Y.M.: re-analyzed the clinical and statistical data and revised the manuscript. All authors read and approved the final manuscript.

Conflicts of interest disclosure

The authors declare no conflicts of interest.

Research registration unique identifying number (UIN)

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Provenance and peer review

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Data availability statement

Data are available from authors on request.

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