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Comparison of the Effectiveness of Intensive Aerobic Exercise, Mindfulness Training, and a Integration of Exercise and Mindfulness on the Academic Performance of Fourth-Grade Elementary Students

Fereshteh Mohammadi [1], Mohammad Javadipour [1*], Ali Nori [2]

1. Department of Psychology and Education of Exceptional Children, Faculty of Psychology and Educational Sciences, University of Tehran, Tehran, Iran.
2. Department of Educational Science, Faculty of Humanities, Malayer University, Malayer, Iran.

***Corresponding Author:** Associate Professor, Department of Methods and Educational Planning and Curriculum, Faculty of psychology and Education, University of Tehran, Iran. Email: javadipour@ut.ac.ir

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ABSTRACT

The aim of this research was to compare the effectiveness of an aerobic exercise program, a mindfulness training program, and a integration of aerobic exercise and mindfulness training on the academic performance of fourth-grade female students. The research method was quasi-experimental with a pre-test and post-test design including a control group. The statistical population consisted of all fourth-grade female students from public elementary schools in Amol city during the academic year 2020-2021, from which 90 students were selected through convenience sampling and assigned to four groups: aerobic exercise program, mindfulness training, integration of aerobic exercise and mindfulness, and a control group (each experimental group consisting of 23 participants and the control group consisting of 21 participants). Subsequently, 18 sessions of 30-minute training were designed and conducted every other day. To collect data in the pre-test and post-test, the Academic Performance Questionnaire by Fam and Taylor (EPT) was used. The data were analyzed using multivariate analysis of covariance and SPSS22 software. The results indicated a significant difference in the academic performance of participants in all three groups: aerobic exercise program (Eta=0.59), mindfulness training (Eta=0.49), and the integration of aerobic exercise and mindfulness (Eta=0.56) compared to the control group ($P \leq 0.05$). However, participants in the integration group of aerobic exercise and mindfulness performed better than the other two training groups. These results suggest that integrating mindfulness training and aerobic exercise can be an effective strategy for improving the academic performance of fourth-grade female students.

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Introduction

Academic performance refers to an individual's acquired or learned ability in educational subjects and is measured through standardized progress tests or teacher-made exams (Samavi et al., 2020). In other words, academic performance signifies the outcome and result of an individual's efforts in relation to formal educational activities, and indeed, all efforts of the educational system are directed towards this phenomenon, which is influenced by various factors as a dependent variable (Fam & Taylor, 1999). The academic performance of learners is the central principle of the entire educational system, and the success or failure of any educational institution is measured by the academic progress of its learners (Shah & Hussain, 2021), such that academic performance is considered one of the fundamental indicators for evaluating and assessing the educational systems of a country (Zhang et al., 2023). The way educational institutions, educators, and students achieve immediate and long-term educational goals is evaluated through academic performance. Learners who perform well in educational environments are better prepared for adulthood and economic and professional success (Grain et al., 2022; Kooren et al., 2024). For this reason, focusing on a better understanding of the factors influencing academic performance is important, and this understanding helps educational institutions improve their educational strategies and provide better learning methods.

Given the importance of the academic performance of education specialists and researchers, efforts are being made to improve it through various methods. Numerous studies have been conducted regarding the effects of sports and different types of physical exercises on academic performance; for example, Li and Zhang (2022) claim that physical activities increase academic success, including extracurricular activities. Additionally, the results of the research by De Greeff et al. (2018) support the positive effects of sports on academic performance, indicating that interventions combined with regular and continuous physical activities over several weeks have the most significant impacts. On the other hand, other studies have shown that, contrary to previous research, sports do not affect academic performance; for instance, Komarudin et al. (2023) conducted a study in which students were divided into three categories: "high activity," "moderate activity," and "no activity," and found no significant correlation between physical activity and students' academic performance. Therefore, research in the area of the effects of sports on executive functions yields inconsistent results, suggesting that this topic requires further study.

In addition, another variable that has been examined for its impact on academic performance is mindfulness. For example, the results of the study by Caballero et al. (2019) showed a significant positive relationship between increased levels of mindfulness and academic success in high school students. Furthermore, Li et al. (2021) demonstrated that mindfulness meditation influences academic success through its beneficial effects on working memory and attention. Similarly, based on the findings of Xu et al. (2022), a virtual intervention based on mindfulness can improve academic performance. On the other hand, some studies have shown that, contrary to previous research, mindfulness does not affect academic performance; for instance, Frank et al. (2017) indicated in their study that no significant changes were observed in academic performance following mindfulness intervention. In this study, academic performance was measured through math and English scores; therefore, the research on the effectiveness of mindfulness on executive functions does not yield consistent results, suggesting that this topic requires further investigation.

Considering that the existing research on the effectiveness of the two interventions, exercise and mindfulness, has not reported uniform results, and that most of these studies have only examined the effectiveness of mindfulness intervention (Caballero et al., 2019) and exercise

(Komarudin et al., 2023) in the experimental group or in comparison with the control group, and given that the existing literature has not addressed the effectiveness of integrating these two on academic performance, the aim of this study was to investigate the effectiveness of aerobic exercise, mindfulness training, and the integration of exercise and mindfulness on the academic performance of fourth-grade elementary school students. Therefore, the fundamental question of this research is whether aerobic exercise, mindfulness training, and the integration of the two are effective on academic performance.

Method

Population, Sample, and Implementation Method

The research method was quasi-experimental with a pre-test and post-test design along with a control group. The statistical population included all fourth-grade female students from public elementary schools in Amol city during the 2020-2021 academic year. Due to the special circumstances arising from the COVID-19 pandemic, 90 individuals were selected using convenience sampling and divided into three experimental groups: aerobic exercise, mindfulness exercises, and a integration of exercise and mindfulness, along with one control group (each experimental group consisting of 23 participants and the control group having 21 participants). Given that the sample was selected from only one public girls' school using a convenience method, the effects of intervening variables such as gender (only female), age (only fourth-grade), and economic factors (only public school) were controlled. Participants were randomly assigned to the experimental and control groups. Subsequently, 18 training sessions of 30 minutes each were designed for each of the interventions, namely aerobic exercise, mindfulness, and the integration of both, and were conducted every other day for the participants in the spring of 2021. The inclusion criteria for the study were: 1- Individual willingness to participate in the intervention program; 2- Obtaining written consent from the family; and not simultaneously using other educational or psychological interventions during the intervention. The exclusion criteria included not completing assignments and being absent for more than two sessions, but none of the participants were excluded from the study. A pre-test and post-test were administered before the start of the training course and after its completion, and the Educational Performance Questionnaire by Fam and Taylor (EPT) was used for data collection in both the pre-test and post-test. The data were analyzed using covariance analysis with SPSS22 software.

Measurement Tools

FAM and Taylor Academic Performance Questionnaire (EPT)

This questionnaire consists of 48 questions and includes five subscales: emotional impacts, self-efficacy, planning, motivation, and lack of control over outcomes. It is scored using a five-point Likert scale (FAM & Taylor, 1999). A score below 120 indicates poor academic performance, a score above 175 signifies excellent academic performance, and scores between 121-174 reflect average academic performance. In Taj (2004), this questionnaire was standardized in Iran, with the overall reliability score based on Cronbach's alpha being 0.74, and the reliability of the subscales being as follows: self-efficacy 0.92, emotional impacts 0.73, planning 0.93, lack of control over outcomes 0.64, and motivation 0.73. In this study, the reliability coefficients based on Cronbach's alpha were as follows: overall score 0.82, self-

efficacy 0.87, emotional impacts 0.76, planning 0.90, lack of control over outcomes 0.74, and motivation 0.80.

Table 1. The components of the questionnaire

Row	Scale	Item
1	Self-efficacy	1-2-3-4-10-25-28-29-30-31-32-33-34-35-36-37-48
2	Emotional effects	11-13-14-15-16-17-18-19-20-27-38-39
3	Planning	5-12-41-44-45-46-47
4	Lack of control	6-7-8-9-24-26-43
5	Motivation	21-22-23-40-42

Method of Implementing Interventions

These interventions include a combined program of aerobic exercise and mindfulness training, as well as aerobic exercise and mindfulness education intervention. The mindfulness training program, which integrates psychological and cognitive-behavioral teaching strategies throughout its implementation, is based on Adams' research (2015), which examined the enhancement of executive functions through mindfulness training in students. The sessions in this highly structured educational program are designed so that new concepts and strategies are taught based on previously learned material. Due to the limitation on the number of pages in the article, detailed descriptions of the session components are not provided, and for further study, one can refer to the original source. The aerobic exercise program was designed and implemented under the supervision of physical education specialists, utilizing their knowledge and experience. The integrated program of aerobic exercise and mindfulness training was also a blend of the mindfulness education program (Adams, 2015) and the aerobic exercise program.

Integrated Program of Aerobic Exercise and Mindfulness Training. This program consists of 9 sessions of mindfulness training and 9 sessions of aerobic exercise, conducted over 18 sessions of 30 minutes each, alternating between aerobic exercise and mindfulness training. Due to the special circumstances arising from the COVID-19 pandemic, all educational programs were provided to students in video format. Students participated in the educational program online and all together.

Table 2. Aerobic exercise sessions

Session	Aim	Session description							
first	Strengthening the thigh abductor muscles	One steps	One heel	Double step side	Double step side	heel 8	Seven steps	easy	march
Second	Strengthening the calf muscles	Heel forward	Heel forward	Heel forward	Heel forward	Lily	Grapevine	Grapevine	Lily
Third	Strengthening the core muscles	Butterfly	march	cross step	seven step	pair of easy step	jumps back	jumps forward	pair of easy step
Fourth	Strengthening the front and back thigh muscles	Mb	Mb	Front mambo	Front mambo	Back toe	Double step side	Double step side	8 counts
Fifth	Strengthening the abdominal muscles	Two knees	marching	forward mambo	forward mambo	two knees	marching	two knees	forward mambo

Sixth	Strengthening the calf muscles	Three heels	Three heels	Three heels	Three heels	Back mambo	Back mambo	Cross step	Double knee
Seventh	Strengthening the hamstrings, buttocks	March	Squat	Back Step	Back Mambo	Cross Step	Double Knee	Double Heel	Step
Eighth	Strengthening the side muscles	Easy step	Jumping feet	open and closed	Marching	Mambo	Side	squat Easy	step back
Ninth	Strengthening the core muscles	Easy step	Jumping feet	open and closed	Marching	Mambo	Side	squat Easy	step back

Table (2) describes the nine aerobic exercise sessions in the combined aerobic exercise and mindfulness training program, broken down by session.

Table 3. Mindfulness sessions

Session description	Aim	Session
first	Introduction to the structure of meetings and the brain	A full explanation of each session's programs and exercises, and a review of them to familiarize yourself with all the key terms before starting the exercises. Help individuals identify the three key parts of the brain involved in thinking and learning.
Second	Metacognitive training, Focus and attention training	Discuss and teach them the signs of intentional thoughts and constructive actions. Our emotions shape our behavior and learning. (Training and strengthening metacognition). Teaching and implementing breathing exercises. Teaching that breathing guides our brain to calm down and focus. (Training and strengthening concentration and attention).
Third	Introduction to executive functions of inhibition, change, and updating	Teach that I can take control of myself (strengthens inhibition, switching, and working memory). Teach people how to direct their attention to the most relevant information in the room (strengthens focus and attention).
Fourth	Strengthening inhibition and change	Teach people how to increase dopamine levels in their brains (fluid intelligence) and teach them that bad responses can be replaced with good ones (strengthening response inhibition and switching).
Fifth	Gratitude training to strengthen mindfulness	Teach people to be grateful because gratitude is one of the most effective factors in enhancing mindfulness, and help them think positively because practice makes it permanent, and help them use happy memories to increase optimistic thinking.
Sixth	Training self-regulation skills through breathing	Help people recognize the importance of being unique and teach them self-regulation skills through breathing, and help them recognize and develop the purposeful capacity of the brain's executive functions with these exercises.
Seventh	Implementing the law of good faith	Implement the Law of Goodwill for School and help people write down a list of things that make them happy to remind them during practice.
Eighth	Summary of key training points	Adding one positive word to the kindness notebook (a notebook where daily positive points are recorded) each day and summarizing key learning points.
Ninth	Reviewing the effectiveness of techniques	Determine how much these techniques have improved people's capacity, and conclude the exercises with a final summary.

Table (3) describes the 9 mindfulness training sessions in the combined aerobic exercise and mindfulness training program, broken down by session.

Aerobic exercise program. This exercise program was conducted in 18 sessions of 30 minutes each, held every other day. It is worth mentioning that the aerobic exercise program for this group is different from the program that combines aerobic exercise with mindfulness. Due to the special circumstances arising from the COVID-19 pandemic, all educational programs were provided to students in video format. Students participated in the training program online, all together.

Table 4. Aerobic exercise sessions

Session	Aim	Session description							
first	Strengthening the thigh abductor muscles	One steps	One heel	Double step side	Double step side	heel 8	Seven steps	easy	march
Second	Strengthening the calf muscles	Heel forward	Heel forward	Heel forward	Heel forward	Lily	Grapevine	Grapevine	Lily
Third	Strengthening the core muscles	Butterfly	march	cross step	seven step	pair of easy step	jumps back	jumps forward	pair of easy step
Fourth	Strengthening the front and back thigh muscles	Mb	Mb	Front mambo	Front mambo	Back toe	Double step side	Double step side	8 counts
Fifth	Strengthening the abdominal muscles	Two knees	marching	forward mambo	forward mambo	two knees	marching	two knees	forward mambo
Sixth	Strengthening the calf muscles	Three heels	Three heels	Three heels	Three heels	Back mambo	Back mambo	Cross step	Double knee
Seventh	Strengthening the hamstrings, buttocks	March	Squat	Back Step	Back Mambo	Cross Step	Double Knee	Double Heel	Step
Eighth	Strengthening the side muscles	Easy step	Jumping feet	open and closed	Marching	Mambo	Side	squat Easy	step back
Ninth	Strengthening the core muscles	Easy step	Jumping feet	open and closed	Marching	Mambo	Side	squat Easy	step back
Tenth	Strengthening the thigh abductor muscles	One steps	One heel	Double step side	Double step side	heel 8	Seven steps	easy	march
Eleventh	Strengthening the calf muscles	Heel forward	Heel forward	Heel forward	Heel forward	Lily	Grapevine	Grapevine	Lily
Twelfth	Strengthening the core muscles	Butterfly	march	cross step	seven step	pair of easy step	jumps back	jumps forward	pair of easy step
Thirteenth	Strengthening the front and back thigh muscles	Mb	Mb	Front mambo	Front mambo	Back toe	Double step side	Double step side	8 counts
Fourteenth	Strengthening the abdominal muscles	Two knees	marching	forward mambo	forward mambo	two knees	marching	two knees	forward mambo
Fifteenth	Strengthening the calf muscles	Three heels	Three heels	Three heels	Three heels	Back mambo	Back mambo	Cross step	Double knee
Sixteenth	Strengthening the hamstrings, buttocks	March	Squat	Back Step	Back Mambo	Cross Step	Double Knee	Double Heel	Step
Seventeenth	Strengthening the side muscles	Easy step	Jumping feet	open and closed	Marching	Mambo	Side	squat Easy	step back
Eighteenth	Strengthening the core muscles	Easy step	Jumping feet	open and closed	Marching	Mambo	Side	squat Easy	step back

Table (4) describes the 18 aerobic exercise sessions in the aerobic exercise program, broken down by session.

Mindfulness Training Program. This training program was conducted over eighteen sessions of 30 minutes each, held every other day. It is important to note that the mindfulness program for this group is different from the mindfulness program for the group integrsted aerobics and mindfulness. However, due to the special circumstances arising from the COVID-19 pandemic, all training sessions were provided to students in video format. The students participated in the training program online and all together.

Table 5. Mindfulness sessions

Session	Aim	Session description
first	Introduction to the structure of meetings and the brain	A full explanation of all the programs and exercises in each session and a review of them to familiarize yourself with all the keywords before starting the exercises. Help identify the three key parts of the brain involved in thinking and learning.
Second	Raisin technique training	People are asked to discuss how they felt after eating a raisin. After 15 minutes of mindfulness, a body scan is performed. For homework, they do the same experience while brushing their teeth or taking a shower.
Third	Metacognition training, focus and attention training	Discuss and teach them the signs of intentional thoughts and constructive actions. Our emotions shape our behavior and learning. (Training and strengthening metacognition). Teaching and implementing breathing exercises. Teaching that breathing guides our brain to calm down and focus. (Training and strengthening concentration and attention).
Fourth	Body scan technique training	Conduct a body scan exercise and discuss the experience. Talk about possible obstacles, such as restlessness and mind wandering, as well as solutions, such as letting go of intrusive thoughts and being nonjudgmental. Talk about the differences between thoughts and feelings and whether they cause emotion directly or through our thoughts and perceptions. Do a body scan for homework.
Fifth	Introducing the executive functions of inhibition, change and updating	Teaching I can take control of myself (strengthens inhibition, switching, and working memory). Students learn how to direct their attention to the most relevant information in the room (strengthens focus and attention).
Sixth	Teaching to avoid judging experiences	Discussion of homework or listening and seeing practice begins. Ask individuals to look around and sit mindfully for 2 minutes. The session ends with examples of avoiding judgment in experiences.
Seventh	Strengthening inhibition and change	Teach people how to increase dopamine levels in their brains (fluid intelligence). Teach students that bad responses can be replaced with good ones (strengthening response inhibition and switching).
Eighth	Implementing meditation in sports performance	Sports focus and body scan, liberation, meditation in sports performance and elimination of distractions and mind control.
Ninth	Using happy memories for optimistic thinking	Help people think positively because practice makes it permanent, and help them use happy memories to increase optimistic thinking.
Tenth	Teaching gratitude to strengthen mindfulness	Help people be grateful because gratitude is one of the most effective factors in enhancing mindfulness.
Eleventh	Teaching self-regulation skills through breathing	Help people recognize the importance of being unique and teach them self-regulation skills through breathing. Help them recognize and develop the purposeful capacity of the brain's executive functions with these exercises.
Twelfth	Creating breathing space	Practice sitting mindfulness. The assignment for subsequent sessions also includes sitting mindfulness and three minutes of breathing space about an unpleasant everyday event.
Thirteenth	Implementing the law of goodwill	Implement the Law of Goodwill for School. Help people write down a list of things that make them happy to remind them during practice.
Fourteenth	Implementing breathing space and mindfulness	Three-minute breathing space practice. Then 15 minutes of mindfulness practice.
Fifteenth	Summarizing key points	Adding a positive word to the kindness notebook (a notebook where daily positive points are recorded). Summarizing key educational points.
Sixteenth	Determining pleasant and unpleasant events	What is the best way to take care of myself? Identifying pleasant and unpleasant events for each person. How can you have a schedule that has many pleasant events. Then doing a three-minute breathing space exercise.

Seventeenth	Reviewing the effectiveness of techniques	Determine how much these techniques have improved people's capacity.
Eighteenth	Reviewing past techniques	Reviewing past material, i.e., a 9-minute mindful body scan and breathing space practice, is the topic of this session. Ask people if they are satisfied with the sessions, whether the sessions have led to their growth, and what skills they have learned.

Data Analysis Method

In this research, data analysis was conducted at two levels: descriptive and inferential. Descriptive statistics were used to calculate descriptive indices, and inferential statistics were employed based on multivariate analysis of covariance to address the research hypotheses. All calculations were performed using SPSS software version 22.

Results

Demographic Description

The participants in this study were 90 fourth-grade female students with an average age of 10 ± 0.5 years from the city of Amol. All participants were from a middle socioeconomic background.

Descriptive Indices

The descriptive indices of the variables, categorized by groups and the stages of pre-test, post-test, and follow-up, are presented in Table (6).

Table 6. Descriptive indices of the groups' academic performance subscales in the pre-test and post-test

Variable	Group	Aerobics training		Mindfulness training		Exercise and mindfulness combined		control	
		Average	SD	Average	SD	Average	SD	Average	SD
Self-efficacy	Pre-test	63.26	3.48	60.87	5.36	69.91	6.32	46.05	7.64
	Post-test	67.74	3.39	75.30	6.00	77.67	6.46	45.62	2.85
Emotional effects	Pre-test	28.39	3.14	24.43	3.00	32.61	3.99	16.38	2.54
	Post-test	30.57	2.54	26.09	2.50	37.00	3.92	16.81	2.18
Planning	Pre-test	13.57	1.08	12.09	1.70	14.26	2.45	8.95	2.20
	Post-test	15/87	0.92	14.48	2.11	19.09	1.70	8.62	1.40
Lack of control	Pre-test	7/85	0.91	6.57	0.72	8.26	1.14	5.09	0.95
	Post-test	9/74	1.14	11.56	1.63	12.91	1.95	3.57	0.93
Motivation	Pre-test	17.01	1.34	16.87	1.31	18.29	2.46	15.43	1.69
	Post-test	19.00	1.78	19.74	1.68	33.36	2.63	6.90	1.89
Academic performance	Pre-test	130.08	4.21	120.83	5.98	146.43	6.29	91.89	8.86
	Post-test	142.91	6.40	150.91	6.56	166.33	11.34	81.52	4.47

Table (6) shows that in the post-test, all subscales as well as the overall academic performance score, participants in the aerobic training, mindfulness training, and exercise-mindfulness integration groups had higher averages compared to participants in the control group. Among the intervention groups, participants in the exercise-mindfulness integration group had a higher average than those in the aerobic training and mindfulness training groups.

Examination of the Assumptions of Parametric Tests

To compare the significance of the descriptive results, analysis of covariance was used. Before conducting the multivariate analysis of covariance, the assumptions were examined. The results of the Shapiro-Wilk test indicated that the distribution of variables by group is normal ($p<0.05$).

Table 7. Results of the Shapiro-Wilk test to examine the normality of the distribution of academic performance.

variable	Group	Shapiro-Wilk	Significance level
Self-efficacy	Aerobics Training	0.97	0.71
	Mindfulness Training	0.96	0.45
	Combining Aerobics and Mindfulness	0.98	0.91
	control	0.97	0.47
Emotional effects	Aerobics Training	0.95	0.27
	Mindfulness Training	0.97	0.69
	Combining Aerobics and Mindfulness	0.95	0.34
	control	0.93	0.15
Planning	Aerobics Training	0.92	0.06
	Mindfulness Training	0.95	0.25
	Combining Aerobics and Mindfulness	0.97	0.78
	control	0.96	0.55
Lack of control	Aerobics Training	0.94	0.14
	Mindfulness Training	0.98	0.84
	Combining Aerobics and Mindfulness	0.92	0.06
	control	0.96	0.43
Motivation	Aerobics Training	0.96	0.47
	Mindfulness Training	0.96	0.45
	Combining Aerobics and Mindfulness	0.95	0.34
	control	0.93	0.16
Academic performance	Aerobics Training	0.94	0.16
	Mindfulness Training	0.97	0.64
	Combining Aerobics and Mindfulness	0.99	0.82
	control	0.95	0.35

Hypothesis Testing

The results of the multivariate analysis of covariance for academic performance in the group combining aerobic exercise and mindfulness and the group performing aerobic exercise are presented in Table (8). Before conducting the analysis, the assumptions were examined. To assess the homogeneity of variance between the two groups—combining aerobic exercise and mindfulness and the aerobic exercise program group—Levene's test for homogeneity of variances was used at the post-test stage. The calculated Levene's test was not statistically significant for any of the variables examined; self-efficacy (F=0.74 and P=0.40), emotional impacts (F=0.001 and P=0.97), planning (F=3.68 and P=0.06), lack of control (F=0.54 and P=0.47), motivation (F=1.66 and P=0.20). Therefore, Levene's test for equality of error variances also indicated that homogeneity of variances was achieved ($p<0.05$). M. Box's test was also used to examine the homogeneity of the covariance matrix. The results indicated that this homogeneity was achieved ($p<0.05$, df1=15, df2=77940.95, F=1.12, Box's M=23.81). In examining the correlation of dependent variables, Bartlett's test showed that there is a moderate and significant correlation among the variables ($p<0.001$, df=14, Bartlett's $\chi^2=110.25$) and the sphericity assumption was met ($P\geq0.05$). Subsequently, multivariate analysis of covariance was employed. The results of Wilks' Lambda test indicated that the differences in adjusted means of academic performance between the two groups—combining aerobic exercise and mindfulness and the aerobic exercise training group—were statistically significant (P=0.001, F=12.22, Wilks' Lambda=0.36). This means that there is a significant difference in academic performance between the groups in the pre-test and post-test. The results of the analysis of

covariance for academic performance in the group combining exercise and mindfulness and the aerobic exercise training group are presented in Table (8).

Table 8. Results of analysis of covariance for differences in academic performance in the combined exercise and mindfulness group and the aerobic exercise group.

variable	Source of variation	Sum of squares	DF	Mean of squares	F	sig	Effect size
Self-efficacy	Pre-test	119.48	1	119.48	6.71	0.01	0.15
	Post-test	197.96	1	197.96	11.12	0.002	0.22
Emotional effects	Pre-test	98.40	1	98.40	12.366	0.001	0.24
	Post-test	0.09	1	0.09	10.92	0.002	0.22
Planning	Pre-test	84.52	1	84.52	10.51	0.002	0.36
	Post-test	0.25	1	0.25	37.40	0.0001	0.49
Lack of control	Pre-test	62.29	1	62.29	9.65	0.04	0.09
	Post-test	2.93	1	2.93	12.07	0.001	0.24
Motivation	Pre-test	117.99	1	117.99	55.63	0.0001	0.59
	Post-test	54.99	1	54.99	25.93	0.0001	0.40

Table (8) shows that in the post-test scores, there is a significant difference between the groups in all subscales of academic performance ($p < 0.05$). This means that the difference observed in the scores of these subscales before and after receiving the integrated aerobic exercise and mindfulness training program is significant when compared to the differences in the pre-test and post-test scores of the executive functions of the participants in the aerobic exercise training group. The effect size of the therapeutic methods for the subscales ranged from 0.09 to 0.59 in change.

The results of the multivariate analysis of covariance for academic performance in the integrated exercise and mindfulness group and the mindfulness group are presented in Table (9). Before conducting the analysis, the assumptions were examined. To assess the homogeneity of variance between the two groups of aerobic integration and mindfulness and the mindfulness group in the post-test phase, Levene's test for equality of variances was used. The calculated Levene's test was not statistically significant for any of the variables examined: self-efficacy ($F = 0.25$, $p = 0.62$), emotional impacts ($F = 2.14$, $p = 0.15$), planning ($F = 0.27$, $p = 0.60$), lack of control ($F = 0.15$, $p = 0.71$), motivation ($F = 0.12$, $p = 0.73$). Therefore, Levene's test for equality of error variances also indicated that homogeneity of variances was achieved ($p < 0.05$). The M. Box test was also used to examine the homogeneity of the covariance matrix. The results showed that this homogeneity was achieved ($p < 0.05$, $df1 = 15$, $df2 = 7794.95$, $F = 1.20$, Box's $M = 23.52$). In examining the correlation of the dependent variables, Bartlett's test indicated that there is a moderate and significant correlation among the variables ($p < 0.05$, $df = 14$, Bartlett's $\chi^2 = 97.80$) and the sphericity assumption was met ($p \geq 0.05$). Subsequently, multivariate analysis of covariance was used. The results of Wilks' Lambda test showed that the differences in the adjusted means of academic performance between the two groups were statistically significant ($p = 0.001$, $F = 36.84$, Wilks' Lambda = 0.16). As a result, there is a significant difference in academic performance between the groups in the pre-test and post-test. The results of the analysis of covariance for academic performance in the integrated exercise and mindfulness group and the mindfulness training group are presented in Table (9).

Table 9. Results of analysis of covariance for differences in academic performance in the integrated exercise and mindfulness group and the mindfulness group.

variable	Source of variation	Sum of squares	DF	Mean of squares	F	sig	Effect size

Self-efficacy	Pre-test	170.27	1	170.27	6.26	0.02	0.14
	Post-test	180.55	1	180.55	6.64	0.01	0.15
Emotional effects	Pre-test	152.39	1	152.39	26.52	0.0001	0.41
	Post-test	800.82	1	800.82	139.36	0.0001	0.78
Planning	Pre-test	13.60	1	13.60	4.53	0.04	0.10
	Post-test	43.29	1	43.29	14.43	0.0001	0.27
Lack of control	Pre-test	34.61	1	34.61	13.71	0.001	0.26
	Post-test	32.90	1	32.90	13.03	0.001	0.25
Motivation	Pre-test	49.63	1	49.63	14.38	0.001	0.27
	Post-test	119.85	1	119.85	34.72	0.0001	0.47

Table (9) shows that there are significant intergroup differences in the post-test scores of all subscales of academic performance ($p < 0.001$). This means that the difference observed in the scores of the subscales of academic performance before and after receiving the integrated curriculum training of aerobic exercise and mindfulness education is significant compared to the differences observed in the pre-test and post-test scores of the academic performance of participants in the mindfulness education group. The effect size of the therapeutic methods for the subscales ranged from 0.14 to 0.78 in change.

The results of the multivariate analysis of covariance for academic performance in the integrated exercise and mindfulness group and the control group are presented in Table (10). Before conducting the analysis, the assumptions were examined. To assess the homogeneity of variance between the two groups of aerobic exercise and mindfulness and the control group in the post-test phase, Levene's test for homogeneity of variances was used. The calculated Levene's test was not statistically significant for any of the variables under investigation: self-efficacy ($F = 0.59$, $p = 0.45$), emotional effects ($F = 1.55$, $p = 0.19$), planning ($F = 1.26$, $p = 0.27$), lack of control ($F = 1.11$, $p = 0.17$), motivation ($F = 1.88$, $p = 0.18$). Therefore, Levene's test for equality of error variances also indicated that homogeneity of variances was achieved ($p < 0.05$). The M. Box test was also used to examine the homogeneity of the covariance matrix. The results showed that this homogeneity was achieved ($p < 0.05$, $df1 = 15$, $df2 = 6966.66$, $F = 1.12$, Box's $M = 26.67$). In examining the correlation of dependent variables, Bartlett's test indicated that there is a moderate and significant correlation among the variables ($p < 0.05$, $df = 14$, Bartlett's $\chi^2 = 95.06$) and the sphericity assumption was met ($p \geq 0.05$). Subsequently, multivariate analysis of covariance was used. The results of Wilks' Lambda test showed that the differences in adjusted means of academic performance are statistically significant ($p = 0.001$, $F = 13.60$, Wilks' Lambda = 0.33). As a result, there is a significant difference in academic performance between the groups in the pre-test and post-test. The results of the analysis of covariance for academic performance in the combined exercise and mindfulness group and the control group are presented in Table (10).

Table 10. Results of analysis of covariance for differences in academic performance in the integrated exercise and mindfulness group and the control group.

variable	Source of variation	Sum of squares	DF	Mean of squares	F	sig	Effect size
Self-efficacy	Pre-test	204.55	1	204.55	13.22	0.001	0.26
	Post-test	270.90	1	270.90	17.51	0.0001	0.32
Emotional effects	Pre-test	279.88	1	279.88	71.68	0.0001	0.66
	Post-test	39.17	1	39.17	10.03	0.0003	0.21
Planning	Pre-test	13.76	1	13.76	6.52	0.02	0.15
	Post-test	28.66	1	28.66	13.59	0.001	0.27
Lack of control	Pre-test	19.37	1	19.37	13.80	0.001	0.27
	Post-test	9.51	1	9.51	6.78	0.01	0.16
Motivation	Pre-test	96.21	1	96.21	47.40	0.0001	0.56
	Post-test	87.13	1	87.13	42.92	0.0001	0.54

Table (10) shows that there are significant intergroup differences in the post-test scores of all subscales of academic performance ($p < 0.001$). This means that the difference observed in the scores of the subscales of academic performance of the participants before and after receiving training in the integrated curriculum of aerobic exercise and mindfulness education is significant compared to the difference observed in the pre-test and post-test scores of the academic performance of the control group participants. The effect size of the therapeutic methods for the subscales ranged from 0.15 to 0.56 in change.

The results of the multivariate analysis of covariance for academic performance in the exercise group and the control group are presented in Table (11). Before conducting the analysis, the assumptions were examined. To assess the homogeneity of variance between the exercise group and the control group in the post-test phase, Levene's test for homogeneity of variances was used. The calculated Levene's test was not statistically significant for any of the variables under investigation: self-efficacy ($F = 3.79$, $p = 0.06$), emotional impacts ($F = 3.86$, $p = 0.06$), planning ($F = 1.47$, $p = 0.23$), lack of control ($F = 2.56$, $p = 0.12$), motivation ($F = 0.16$, $p = 0.69$). Therefore, Levene's test for equality of error variances also indicated that homogeneity of variances was achieved ($p < 0.05$). The M. Box test was also used to examine the homogeneity of the covariance matrix. The results showed that this homogeneity was achieved ($p < 0.05$, $df1 = 15$, $df2 = 6966.66$, $F = 1.26$, Box's $M = 21.73$). In examining the correlation of dependent variables, Bartlett's test indicated that there is a moderate and significant correlation among the variables ($p < 0.05$, $df = 14$, Bartlett's $\chi^2 = 44.58$) and the sphericity assumption was met ($p \geq 0.05$). Subsequently, multivariate analysis of covariance was used. The results of Wilks' Lambda test showed that the differences in adjusted means of academic performance are statistically significant ($p = 0.001$, $F = 10.47$, Wilks' Lambda = 0.39). As a result, there are significant differences between the groups in the pre-test and post-test academic performance. The results of the analysis of covariance for academic performance in the exercise group and the control group are presented in Table (11).

Table 11. Results of analysis of covariance for differences in academic performance in the aerobic exercise and control group

variable	Source of variation	Sum of squares	DF	Mean of squares	F	sig	Effect size
Self-efficacy	Pre-test	25.27	1	25.27	5.01	0.03	0.12
	Post-test	71.72	1	71.72	14.22	0.001	0.28
Emotional effects	Pre-test	46.56	1	46.56	10.10	0.003	0.21
	Post-test	20.74	1	20.74	4.50	0.04	0.11
Planning	Pre-test	12.78	1	12.78	10.59	0.002	0.22
	Post-test	15.93	1	15.93	13.20	0.001	0.26
Lack of control	Pre-test	6.43	1	6.43	6.57	0.02	0.15
	Post-test	10.85	1	10.85	11.08	0.002	0.23
Motivation	Pre-test	77.59	1	77.59	53.95	0.001	0.59
	Post-test	37.67	1	37.67	26.20	0.001	0.42

Table (11) shows that there are significant intergroup differences in the post-test scores of all subscales of academic performance ($p < 0.001$). This means that the difference observed in the scores of the subscales of academic performance of the participants before and after receiving aerobic exercise training is significant compared to the differences in the pre-test and post-test scores of the academic performance of the control group participants. The effect size of the treatment methods for the subscales ranged from 0.11 to 0.59 in change.

The results of the multivariate analysis of covariance for academic performance in the mindfulness group and the control group are presented in Table (12). Before conducting the analysis, the assumptions were examined. To assess the homogeneity of variance between the mindfulness group and the control group at the post-test stage, Levene's test for homogeneity

of variances was used. The calculated Levene's test was not statistically significant for any of the variables examined; self-efficacy ($F = 2.77$, $p = 0.08$), emotional impacts ($F = 2.17$, $p = 0.15$), planning ($F = 0.6$, $p = 0.82$), lack of control ($F = 1.04$, $p = 0.31$), motivation ($F = 0.93$, $p = 0.34$). Therefore, Levene's test for equality of error variances also indicated that homogeneity of variances was achieved ($p < 0.05$). The M. Box test was also used to examine the homogeneity of the covariance matrix. The results showed that this homogeneity was achieved ($p < 0.05$, $df1 = 15$, $df2 = 6966.66$, $F = 1.02$, Box's $M = 26.39$). In examining the correlation of the dependent variables, Bartlett's test indicated that there is a moderate and significant correlation among the variables ($p < 0.05$, $df = 14$, Bartlett's $\chi^2 = 98.59$) and the sphericity assumption was met ($p \geq 0.05$). Subsequently, multivariate analysis of covariance was used. The results of Wilks' Lambda test showed that the differences in the adjusted means of academic performance are statistically significant ($p = 0.001$, $F = 11.42$, Wilks' Lambda = 0.37). As a result, there is a significant difference between the groups in the pre-test and post-test academic performance. The results of the analysis of covariance for academic performance in the mindfulness group and the control group are presented in Table (12).

Table 12. Results of analysis of covariance for differences in academic performance in the mindfulness and control group

variable	Source of variation	Sum of squares	DF	Mean of squares	F	sig	Effect size
Self-efficacy	Pre-test	82.23	1	82.23	4.18	0.05	0.10
	Post-test	249.61	1	249.61	12.69	0.001	0.26
Emotional effects	Pre-test	98.33	1	98.33	33.95	0.001	0.48
	Post-test	14.06	1	14.06	4.85	0.03	0.12
Planning	Pre-test	18.40	1	18.40	8.99	0.005	0.20
	Post-test	12.34	1	12.34	6.04	0.02	0.14
Lack of control	Pre-test	25.93	1	25.93	16.69	0.002	0.31
	Post-test	15.25	1	15.25	9.82	0.003	0.21
Motivation	Pre-test	17.52	1	17.52	6.25	0.02	0.14
	Post-test	53.59	1	53.59	19.10	0.001	0.34

Table (12) shows that there are significant differences between groups in the post-test scores of all subscales of academic performance ($p < 0.001$). This means that the difference observed in the scores of the subscales of academic performance of the participants before and after receiving mindfulness training is significant compared to the differences in the pre-test and post-test scores of the academic performance of the control group participants. The effect size of the therapeutic methods for the subscales ranged from 0.10 to 0.48 in change.

As a result, the comparison among the interventions indicates that all three educational groups had a significant impact on the academic performance of fourth-grade elementary students compared to the control group; however, the effectiveness of the combined aerobic exercise and mindfulness program was greater than that of the other two educational groups.

Discussion and Conclusion

The aim of this study was to compare the effectiveness of aerobic exercise, mindfulness training, and a integration of aerobic exercise and mindfulness on the academic performance of fourth-grade elementary school students using a quasi-experimental design with a pre-test and post-test with a control group. Overall, the results indicated a significant difference in academic performance among participants in all three groups: the aerobic exercise program, mindfulness training, and the integration of aerobic exercise and mindfulness compared to the control group. However, participants in the combined aerobic exercise and mindfulness training group performed better than the other two groups, namely the aerobic exercise program and mindfulness training.

Considering the results, there is a significant difference in academic performance among students participating in the mindfulness training program compared to the control group, which aligns with the research by Line et al. (2018), Xu et al. (2022), and Li et al. (2021), but is inconsistent with the findings of Frank et al. (2017). Mindfulness is associated with mental health (Wang, 2022), and interventions based on mindfulness, such as mindfulness-based stress reduction and mindfulness-based cognitive therapy, are effective in reducing stress and emotional turmoil (Chetlen et al., 2019), which consequently has a significant impact on cognitive and emotional health in youth and ultimately academic success (Boo et al., 2020). Mindfulness has the ability to improve executive functions related to academic performance, such as attention and information processing (Lin et al., 2018), as it significantly affects the increase in attention capacity, which is an important factor in academic engagement (Boo et al., 2020). Additionally, mindfulness meditation influences academic success through its beneficial effects on working memory and attention (Li et al., 2021).

The results also indicated a significant difference in academic performance among students participating in aerobic exercise compared to the control group. These findings align with the research by Li & Zhang (2022) and De Greeff et al. (2018), but do not align with the study by Komarudin et al. (2023). Aerobic exercise activities improve creativity after a training period, which is important for academic advancement, as aerobic exercises induce specific changes in the brain that lead to a direct neurochemical response, potentially enhancing cognitive performance (Latorre Román et al., 2018). Physical activity is associated with increased release of neurotrophic molecules such as brain-derived neurotrophic factor (BDNF), which enhances learning and cognition (Latino et al., 2023). On the other hand, BDNF promotes neuroprotection, cell survival, and synaptic plasticity (Lin et al., 2018), and furthermore, continuous physical activity can increase the number of neurons, dendrites, synapses, and essential structural elements throughout the peripheral and central nervous systems (Donnelly et al., 2016), all of which facilitate learning and cognitive functions.

The results also showed a significant difference in academic performance among students participating in the combined aerobic exercise and mindfulness group compared to the control group. Integrating aerobic exercise and mindfulness training improves executive functions (Mohammadi, Javadipour, Nouri, 2024), which is a factor affecting academic performance (nazari et al, 2017). Studies have demonstrated that the Mental and Physical Activity Program (MAP), which integrates meditation and aerobic exercise, is associated with an increased frequency of primary components of the recall response in the flanker task, engaging neural processes related to executive functions such as working memory, which is linked to academic performance (Elderman et al., 2016). Additionally, aerobic exercise induces specific changes in the brain that lead to a direct neurochemical response, potentially enhancing cognitive performance (Latorre Román et al., 2018), and mindfulness has the ability to improve executive functions related to academic performance, such as attention and information processing (Lin et al., 2018).

One of the limitations is the demographic characteristics of the sample (gender and educational level), as this study was conducted only among fourth-grade female students, and generalizing the results to other populations should be done with caution. On the other hand, due to the special circumstances arising from the COVID-19 pandemic, all educational programs were provided to students in video format, and there was no opportunity to assess the learning outcomes of the students in these educational programs. The lack of control over confounding variables, such as psychiatric disorders, may also be another limitation of the present study.

To enhance the generalizability of the results across different groups, it is recommended that future research includes samples from other age groups and demographic characteristics.

Additionally, the use of in-person educational programs could increase participation and learning among individuals.

Considering the results obtained and the impact of combining aerobic exercise and mindfulness training on academic performance and success, it is suggested that, according to the protocol of this research, aerobic and mindfulness exercises be conducted every other session by students under the supervision of specialists to maximize the effects. Therefore, aerobic exercise should be officially implemented during physical education classes in schools, and a suitable space should be provided for its execution. Furthermore, it is recommended to involve specialists and formally teach mindfulness in schools to witness improvements in students' executive functions and, consequently, their academic performance and success.

Declarations

Author Contributions

Conceptualization, F.M. & M.J. Methodology, F.M. & A.N. Software, F.M.; Validation, M.J., A.N.; Formal analysis, F.M.; Investigation, F.M.; Resources, F.M.; Data curation, F.M.; Writing—original draft preparation, F.M.; Writing—review and editing, M.J. & A.N.; Visualization, M.J.; Supervision, M.J. (advisor), A.N. (consultant); Project administration, F.M. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Ethical considerations

In this research, all ethical standards were observed, including informed consent from participants and parents, ensuring the confidentiality of individuals' information, and voluntary participation and withdrawal of individuals. Additionally, ethical considerations were addressed in accordance with research ethics principles.

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Conflict of interest

The authors declare that there is no conflict of interest in reporting the results of this research.

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