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The Effects of Complex Attention Training on Brain Function Index and Attention Concerntration Adolescents with ADHD

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ADHD 청소년의 복합 주의집중 훈련이 뇌기능 지수와 주의집중력에 미치는 영향

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Abstract This study aims to investigate the effects of an 8-week complex attention concentration program on the brain function index and attention concentration in adolescents with ADHD. The subjects of the study were 18 male adolescents from H School located in I City, divided into three groups: 6 participants in the complex attention concentration program group, 6 in the target-related physical activity group, and 6 in the no-treatment control group. Data analysis included calculating means and standard deviations for group comparisons, and two-way (2RM×6RM) ANOVA was conducted to test differences at various measurement points. Post-hoc tests were performed to examine significant interaction effects (p<.05). The results indicated that the integrated attention training program had a more positive effect on brain function sub-indices compared to both the target-related physical activity group and the no-treatment group. Similarly, the program showed a more positive effect on attention levels compared to the other two groups. Based on these results, it can be concluded that the integrated attention training program significantly improves overall brain function in ADHD students and is advantageous due to its ease of participation. It is suggested that this program could be widely used due to these benefits.

Key Words : ADHD, Integrated Attention Training Program, Brain Function Index, Attention Levels, FAIR Test

요 약 본 연구는 ADHD 청소년들에게 8주간 복합 주의집중 프로그램을 적용하여 뇌기능지수와 주의집중력에 미치는 영향을 규명하는데 있다. 연구 대상은 I시 소재 H학교 남자 청소년 총 18명으로 복합 주의 집중 프로그램 6명, 표적 관련 신체활동 6명, 무처치 6명이었다. 자료분석은 집단별 비교 분석을 위해 평균과 표준편차를 산출하였고, 집단별 측정 시점에 따른 차이 검증하기 위해 two-way(2RM×6RM)ANOVA를 실시하였다. 상호작용 효과에서 유의한 차이검증은 대비검증을 실시하였다(p<.05). 결과로 ADHD 학생들에 복합 주의 집중 프로그램이 뇌기능 지수의 하위지표에서 표적 관련 신체활동과 무처치 집단 보다 긍정적인 효과를 나타냈고, ADHD 학생들에 복합 주의 집중 프로그램이 주의집중력에서 표적 관련 신체활동과 무처치 집단 보다 긍정적인 효과를 나타냈다. 분석된 결과를 통해 다음과 같은 결론을 얻었다. 복합 주의 집중 프로그램 실시 후 ADHD 학생의 뇌 기능의 전반적인 변화를 의미하는 것으로 복합 주의 집중 프로그램이 부담 없이 쉽게 참여할 수 있다는 장점이 있어 폭넓게 활용될 수 있을 것으로 판단된다.

키워드 : ADHD, 복합주의집중프로그램, 뇌기능지수, 주의집중력, FAIR 검사

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1. Introduction

Attention-Deficit Hyperactivity Disorder (ADHD), characterized by inattention, hyperactivity, and impulsivity, is one of the most common disorders among school-aged children. ADHD is approximately three times more prevalent in boys than in girls[1].

An epidemiological survey conducted by Seoul City and Seoul National University Hospital revealed that the number of ADHD cases increased from 6,198 in 2003 to 25,429 in 2008, a fourfold rise[2]. This surge in prevalence not only raises concerns about the disorder but also affects academic performance. Students with ADHD often exhibit low attention, leading to persistent distractibility and difficulties in completing tasks, which results in lower academic achievement[3]. Additionally, ADHD can lead to problematic behaviors that interfere with peer relationships and daily life[4].

If untreated during childhood, ADHD symptoms are highly likely to persist into adolescence and adulthood[5,6]. Early detection and treatment are crucial due to associated issues such as low self- esteem, depression, anxiety, learning disabilities, family conflicts, and psychological burdens[7].

The neurophysiological causes of ADHD include frontal lobe dysfunction, decreased levels of dopamine and norepinephrine[1], metabolic disorders, genetic anomalies, environmental factors, impaired perception and cognitive function, attention arousal, and inhibitory control deficits[8]. Imbalanced development of the left and right brain hemispheres[9] also contributes to the disorder. While medication is the most commonly used treatment, physical activity interventions that affect brain neurotransmitters and the central nervous system are also needed due to the potential side effects of cardiovascular diseases associated with medication [10,11].

Research on educational interventions for ADHD has actively focused on improving attention. Studies utilizing neurofeedback, which enhances brain self-regulation by allowing individuals to see their brainwave information directly, include work by Kwon[12], Kim[13], and Yoo[14]. However, most of these studies focus on impulse control or therapeutic interventions.

Research utilizing physical activity includes studies on sports activities[15], target-based play activities to enhance attention[16], physical activities using gymnastics, dance, and tools[17,18], sensory or perceptual training[19], and horseback riding[20]. Despite these diverse interventions, there is a lack of research on which intervention is most effective for ADHD. Additionally, studies combining neurofeedback and target-based physical activities to enhance attention are scarce.

Therefore, research is needed to examine the effects of combining brainwave-based brain activation and control training with target-based attention-enhancing physical activities on attention and brain function in ADHD students. The aim of this study is to identify the impact of an 8-week integrated attention training program on brain function indices and attention levels in middle and high school students with ADHD.

2. Method

2.1 Research Participants

The participants in this study were 18 male students from H School in Incheon Metropolitan City, consisting of 4 second-year middle school students, 5 third-year middle school students, 5 first-year high school students, and 4 second-year high school students. They were selected based on a diagnosis following the DSM-IV criteria, and had received medical approval to participate in the experiment. Participants were chosen from those who were not currently taking ADHD-related medication and had no other psychiatric disorders apart from ADHD.

Before the experiment, participants were informed about the study's content and procedures,

provided written consent, and voluntarily agreed to participate in the study. The physical characteristics of the participants are shown in 〈Table 1〉.

Table 1. Characteristics of the research subjects

(M±SD)

Group	n	Age (year)	Height (cm)	Weight (kg)
E·G	6	16.60±1.00	167.88±5.68	68.53±9.38
T·G	6	16.88±1.11	167.05±5.55	67.07±8.28
C·G	6	16.80±1.30	166.07±5.28	68.03±9.40

M: Mean, SD: standard deviation
E·G: Experimental Group for the complex attention-focused program
T·G: Comparison Group for targeted physical activity
E·G: Control Group

2.2 Experimental Design and Procedure

This study utilized a repeated-measures experimental design to investigate the impact of an integrated attention training program on attention levels and brain function indices in students with ADHD. The experimental groups included an integrated attention training program group, a target-related physical activity comparison group, and a no-treatment control group. The changes in brain function indices and attention levels were set as dependent variables.

The overall experimental procedure involved randomly assigning participants to the integrated attention training program group, the target-related physical activity comparison group, or the no-treatment control group. Brain function indices and attention levels were measured before and after the 8-week integrated attention training program and the target-related physical activity intervention. 〈Table 2〉 illustrates the overall experimental procedure.

Table 2. Experimental procedure

Group	Pre-test	Experimental Treatment	Post-test
Experimental Group	O_1,	☆	O_2
Comparison Group	O_3	○	O_4
Control Group	O_5		O_6

O_1, O_3 O_5: Pre-test (Brain Function Index, FAIR Test),
O_2 O_4 O_6: Post-test (Brain Function Index, FAIR Test),
☆: Integrated Attention Training Program,
○: Target-Related Physical Activity

2.3 Measurement Methods

2.3.1 Brain Function Measurement

For measuring brain function in this study, the NeuroHarmony M, a 2-channel EEG device manufactured by Braintech, was used. The brain function measurement was conducted as follows: A headband with gold-plated solid electrodes spaced 4cm apart was attached to the participant's forehead. The headband had electrodes placed at FP1, FPz, and FP2 positions.

A reference electrode was fixed to the participant's left earlobe. The participant was instructed to sit in a chair and maintain a proper posture. The procedures for measuring EEG were explained to the participant. EEG measurements were taken before and after the 8-week integrated attention training program. Three brain function indices were used from the EEG data: Self-Regulation Index (SRQ), Attention Index (ATQ), and Brain Index (BQ). 〈Table 3〉 presents the related frequencies and analytical components of the eight brain function indices analyzed during EEG measurements.

Table 3. The relevant frequencies and analytical elements of the brain function index

Brain Function index	Relevant frequency	Analytical elements
Self-regulation index	α, SMR, βlow	Brain's autonomic nervous system regulation ability
Attention index	θ, SMR, δ, βhigh	Brain's arousal and immune function
Activation index	α, βlow	Brain's activation state
Emotional index	Left α, Right α	Emotional balance
Left-right brain balace index	Left-Right all	Left-right symmetry in intensity and balance in synchronicity
Brain index		Overall brain function

The brain function measurement system used for this study measured EEG frequencies in the range of 1-30 Hz. The training modes included relaxation, attention, and concentration, focusing on key wavelength bands: alpha waves (8-12 Hz), SMR waves (13-15 Hz), and low beta waves (16-20 Hz).

Data analysis of the raw EEG data was performed using the Brain Function Analysis Program (BQ Test ver1.0, Brain See) from the Korean Institute of Psychiatric Science. The Fast Fourier Transform (FFT) method was employed to convert the data, decomposing the waveform into its fundamental and harmonic frequencies, and then calculating the amplitude for each frequency by taking the square root of the amplitude values.

2.3.2 FAIR Attention Test

The FAIR Attention Test was administered after assigning groups with ADHD and conducting homogeneity tests for each group. The test was also administered before and after the 8-week integrated attention training program. During the FAIR Attention Test, participants were instructed to sit in a chair and maintain proper posture, and the content and procedures of the test were explained.

The FAIR Attention Test involves a single sheet with a grid of 30x30 squares containing 4 types of shapes. Participants were required to find two specific shapes (a square with 2 dots and a circle with 3 dots) among the grid. The procedure involved drawing lines from left to right under the shapes, marking the shapes with a jagged line when they were found, and continuing until all specified shapes were detected. The test was administered twice for 3 minutes each, with split-half reliability applied.

Data analysis of the FAIR Attention Test measured: Selective Ability Index (P): Reflects the ability to process information within the given time, related to selective attention. Quality-Control Ability Index (Q): Represents the proportion of correct judgments and is related to self-control. Sustained Attention Ability Index (C): Indicates the extent of sustained attention, associated with brain energy activation levels such as arousal and activation. 〈Table 4〉 provides information on the related abilities, scoring methods, and reliability of the FAIR Attention Test indices.

Table 4. Attention concentration test index

Test index	Relevant index	Scoring method	Reliability
P(selection ability index)	Selective attention	(T-EL)-2(EO+EC)	.944
Q(Quality control index)	Self-control	P÷T	.903
C(Continuity index)	Sustained attention	p×Q	.941

T: Total number of items worked on
EL: Total number of errors in drawing lines
EO: Total number of target items not marked with a jagged line
EC: Total number of non-target items incorrectly marked with a jagged line

2.4 Complex Attention Training Program

The 8-week Complex Attention Training Program (experimental group) and Target-Related Physical Activity (comparison group) were conducted 3 times a week, with each session lasting 50 minutes. To maintain student interest and ensure continuous engagement, a 2-minute break was provided at each stage. Additionally, the difficulty was adjusted every 2 weeks, with a total of 4 stages of difficulty.

In the Complex Attention Training Program, brainwave training was conducted for 20 minutes, with the following programs assigned: Weeks 1-2 involved a brain health program, Weeks 3-4 a racing program, Weeks 5-6 a memory and cognitive program, and Weeks 7-8 a brain relaxation program. The training method involved attaching the NeuroHarmony M headband to the frontal lobe and guiding the participant to observe and correct their brainwave state using a mirror. Each session began with measuring the participant's brainwaves to collect baseline information and included breathing control exercises to help relax.

Target-Related Physical Activities included Tuho (a traditional Korean game), darts, and bowling (with plastic bottles). The experimental group participated in each activity for 10 minutes, while the comparison group engaged in each activity for 15 minutes. To keep students interested and engaged, a 2-minute break was also provided at each stage. 〈Table 5〉 shows the details of the Complex Attention Training Program, and 〈Table 6〉

illustrates the Target-Related Physical Activity Program.

2.5 Data Processing

Data processing for this study was carried out using the SPSS (Statistical Packages for Social Science) ver. 21.0 program. Descriptive statistics were used to calculate the mean (M) and standard deviation (SD) for each measurement item to compare groups. Two-way (2RM×6RM) ANOVA was conducted to verify differences in self-regulation index, attention index, brain index, selective attention, self-control, and sustained attention across measurement points. If significant interaction effects were found, contrast (post-hoc) tests were performed. The statistical significance level for this study was set at $p<.05$.

3. Research Results

3.1 Brain Function Index

3.1.1 Self-Regulation Index

The descriptive statistics of the Self-Regulation Index measured before and after the 8-week Complex Attention Training Program are presented in Table 7.

Table 5. Complex attention concentration program

Stage	Duration(week)	Program	Difficulty level	Exercise time	Rest
Stage (brainwave training)	1-2	Brain health training		10 minutes for each stage	
	3-4	Racing training			
	5-6	Memory and thinking skills training			
	7-8	Brain tension training			2 minutes after stage 1
Stage 2 (tuho)	1-2	2 meters away from the tuho container	Beginner		
	3-4	2.5 meters away from the tuho container	Intermediate		
	5-6	3 meters away from the tuho container	Advanced		
	7-8	3.5 meters away from the tuho container	Expert		2 minutes after stage 2
Stage 3 (darts)	1-2	1 meter away from the dartboard	Beginner		
	3-4	2 meter away from the dartboard	Intermediate		
	5-6	3 meter away from the dartboard	Advanced		
	7-8	4 meter away from the dartboard	Expert		2 minutes after stage 3
Stage 4 (bowling)	1-2	5 meters away from the plastic bottle	Beginner		
	3-4	6 meters away from the plastic bottle	Intermediate		
	5-6	7 meters away from the plastic bottle	Advanced		
	7-8	8meters away from the plastic bottle	Expert		

Table 6. Target-related physical activity program

Stage	Duration(week)	Program	Difficulty level	Exercise time	Rest
Stage 1 (tuho)	1-2	2 meters away from the tuho container	Beginner	15 minutes for each stage	
	3-4	2.5 meters away from the tuho container	Intermediate		
	5-6	3 meters away from the tuho container	Advanced		
	7-8	3.5 meters away from the tuho container	Expert		2 minutes after stage 1
Stage 2 (darts)	1-2	1 meter away from the dartboard	Beginner		
	3-4	2 meter away from the dartboard	Intermediate		
	5-6	3 meter away from the dartboard	Advanced		
	7-8	4 meter away from the dartboard	Expert		2 minutes after stage 2
Stage 3 (bowling)	1-2	5 meters away from the plastic bottle	Beginner		
	3-4	6 meters away from the plastic bottle	Intermediate		
	5-6	7 meters away from the plastic bottle	Advanced		
	7-8	8meters away from the plastic bottle	Expert		

Table 7. Pre and post self-regulation index by group

	group	n	pre M±SD	post M±SD
Self-regulation index	a	6	60.83±1.17	77.33±1.03
	b	6	60.17±0.75	64.33±0.82
	c	6	60.67±0.82	67.22±7.62
a: Experimental group, b: Comparison group, c: Control group				

As shown in Table 8, the pre- and post- intervention self-regulation indices for the compound attention training program were as follows: Experimental group: Pre 60.83±1.17 Post 77.33±1.03, Comparison group: Pre 60.17±0.75 Post 64.33±0.82, Control group: Pre 60.67±0.82 Post 67.22±7.62.

This indicates that the self-regulation indices increased for all groups from pre- to post-intervention. Results from a repeated measures two-way ANOVA showed significant differences in self-regulation indices between groups (F=321.80, p=.000). There were also significant differences in self-regulation indices at pre- and post- measurement points within each group (F=507.04, p=.000), and significant interaction effects between groups and measurement points (F=297.99, p=.000). Additionally, post-hoc comparisons revealed that the experimental group had the highest self-regulation indices compared to the comparison and control groups (see Table 8).

Table 8. Two-way ANOVA for pre and post self-regulation index by group

Source of variance	Sum of squares	*df*	*MS*	*F*	*p*	Contrast
Group	507.72	2	253.86	321.80	.000	a)b)c
error	11.83	15	.79			
measurement time point	400.00	1	400.00	507.04	.000	
Group×time point	470.17	2	235.08	297.99	.000	
Error(time point)	11.83	15	.79			

a: Experimental group, b: Comparison group, c: Control group

3.1.2 Attention Index

The descriptive statistics of the attention indices measured before and after the 8-week compound attention training program are shown in Table 9.

As shown in Table 9, the attention indices measured before and after the 8-week compound attention training program were as follows: Experimental group: Pre 55.50±1.87 Post 65.33±1.03, Comparison group: Pre 57.33±0.82 Post 61.67±0.82, Control group: Pre 56.56±1.42 Post 61.11±3.89

Table 9. Pre and post attention index by group

	group	n	pre M±SD	post M±SD
Attention index	a	6	55.50±1.87	65.33±1.03
	b	6	57.33±0.82	61.67±0.82
	c	6	56.56±1.42	61.11±3.89
a: Experimental group, b: Comparison group, c: Control group				

This indicates that the attention indices increased for each group from pre- to post-intervention. Results from a repeated measures two-way ANOVA to examine the differences in attention indices between groups and at pre-and post-measurement points are shown in Table 10. Significant differences in attention indices were found between groups (F=48.62, p=.000). There were also significant differences in attention indices at pre- and post-measurement points within each group (F=134.48, p=.000), and significant interaction effects between groups and measurement points (F=57.74, p=.000). Post-hoc comparisons revealed that there were no significant differences between the experimental group and the comparison group, while the control group had the lowest attention indices.

Table 10. Two-way ANOVA for pre and post attention index by group

Source of variance	Sum of squares	*df*	*MS*	*F*	*p*	Contrast
Group	96.17	2	48.08	48.62	.000	a, b)c
error	14.83	15	.989			
measurement time point	186.78	1	186.78	134.48	.000	
Group×time point	160.39	2	80.19	57.74	.000	
Error (time point)	20.83	15	1.39			

a: Experimental group, b: Comparison group, c: Control group

3.1.3 Brain Index

The descriptive statistics of the brain indices measured before and after the 8-week compound attention training program are shown in Table 11.

As shown in Table 11, the brain indices measured before and after the 8-week compound attention training program were as follows: Experimental group: Pre 61.83±1.69 Post 76.17±1.17, Comparison group: Pre 63.00±1.55 Post 64.17±4.02, Control group: Pre 62.00±1.14 Post 66.83±7.37

Table 11. Pre and post brain index by group

	group	n	pre M±SD	post M±SD
Brain index	a	6	61.83±1.69	76.17±1.17
	b	6	63.00±1.55	64.17±4.02
	c	6	62.00±1.14	66.83±7.37

a: Experimental group, b: Comparison group, c: Control group

This indicates that the brain indices increased for each group from pre- to post-intervention. Results from a repeated measures two-way ANOVA to examine the differences in brain indices between groups and at pre- and post-measurement points are shown in Table 12.

Significant differences in brain indices were observed between groups (F=40.19, p=.000). Significant differences in brain indices were also found at pre- and post-measurement points within each group (F=92.53, p=.000), and significant interaction effects between groups and measurement points were noted (F=90.92, p=.000). Additionally, post-hoc comparisons showed that the experimental group had the highest brain indices compared to the comparison and control groups.

Table 12. Two-way ANOVA for pre and post brain index by group

Source of variance	Sum of squares	*df*	*MS*	*F*	*p*	Contrast
Group	429.17	2	214.58	40.19	.000	a>b>c
error	80.08	15	5.34			
measurement time point	210.25	1	210.25	92.53	.000	
Group×time point	413.17	2	206.58	90.92	.000	
Error(time point)	34.08	15	2.27			

a: Experimental group, b: Comparison group, c: Control group

3.2 Attention

3.2.1 Selective Attention

The descriptive statistics of selective attention measured before and after the 8-week compound attention training program are shown in Table 13.

As shown in Table 13, the selective attention measured before and after the 8-week compound attention training program was as follows: Experimental group: Pre 143.00±2.10 Post 186.33±3.88, Comparison group: Pre 137.83±2.14 Post 151.17±4.22, Control group: Pre 142.00±2.45 Post 140.17±4.67.

Table 13. Pre and post selective attention by group

	group	n	pre M±SD	post M±SD
selective attention	a	6	143.00±2.10	186.33±3.88
	b	6	137.83±2.14	151.17±4.22
	c	6	142.00±2.45	140.17±4.67

a: Experimental group, b: Comparison group, c: Control group

This indicates that selective attention increased from pre- to post-intervention in both the experimental and comparison groups, while it slightly decreased in the control group. Results from a repeated measures two-way ANOVA to examine the differences in selective attention between groups and at pre- and post-measurement points are shown in Table 14.

Significant differences in selective attention were observed between groups (F=105.51, p=.000). Significant differences in selective attention were also found at pre- and post-measurement points within each group (F=637.46, p=.000), and significant interaction effects between groups and measurement points were noted (F=336.05, p=.000). Additionally, post-hoc comparisons revealed that the experimental group had the highest selective attention, while there were no significant differences between the comparison and control groups.

Table 14. Two-way ANOVA for pre and post selective attention by group

Source of variance	Sum of squares	*df*	*MS*	*F*	*p*	Contrast
Group	3898.17	2	1949.08	105.51	.000	a>b, c
error	277.08	15	18.42			
measurement time point	3006.69	1	3006.69	637.46	.000	
Group×time point	3170.06	2	1585.03	336.05	.000	
Error (time point)	70.75	15	4.72			

a: Experimental group, b: Comparison group, c: Control group

3.2.2 Self-Control

The descriptive statistics of self-control measured before and after the 8-week compound attention training program are shown in Table 15.

As shown in Table 15, the self-control measured before and after the 8-week compound attention training program was as follows: Experimental group: Pre 0.87±0.01 Post 0.97±0.01, Comparison group: Pre 0.88±0.01 Post 0.89±0.01, Control group: Pre 0.87±0.01 Post 0.87±0.01

Table 15. Pre and post self-control by group

	group	n	pre M±SD	post M±SD
self-control	a	6	0.87±0.01	0.97±0.01
	b	6	0.88±0.01	0.89±0.01
	c	6	0.87±0.01	0.87±0.01

a: Experimental group, b: Comparison group, c: Control group

This indicates that self-control increased from pre- to post-intervention in both the experimental and comparison groups, while there was no change in the control group. Results from a repeated measures two-way ANOVA to examine the differences in self-control between groups and at pre- and post-measurement points are shown in Table 16. Significant differences in self-control were found between groups (F=30.94, *p*=.000). Significant differences in self-control at pre- and post-measurement points were also observed within each group (F=605.00, *p*=.000), and significant interaction effects between groups and measurement points were noted (F=515.00, *p*=.000). Additionally, post-hoc comparisons revealed that the experimental group had higher self-control, with no significant differences between the comparison and control groups.

Table 16. Two-way ANOVA for pre and post self-control by group

Source of variance	Sum of squares	*df*	*MS*	*F*	*p*	Contrast
Group	0.02	2	0.01	30.94	.000	a>b, c
error	0.00	15	.000			
measurement time point	0.01	1	0.01	605.00	.000	
Group×time point	0.02	2	0.01	515.00	.000	
Error (time point)	0.00	15				

a: Experimental group, b: Comparison group, c: Control group

3.2.3 Sustained Attention

The descriptive statistics of sustained attention measured before and after the 8-week compound attention training program are shown in Table 17.

As shown in Table 17, the sustained attention measured before and after the program was as follows: Experimental group: Pre 122.00±2.10 Post 166.33±3.88, Comparison group: Pre 122.83±2.32 Post 131.67±5.16, Control group: Pre 122.00±2.10 Post 121.67±3.08.

Table 17. Pre and post sustained attention by group

	group	n	pre M±SD	post M±SD
sustained attention	a	6	122.00±2.10	166.33±3.88
	b	6	122.83±2.32	131.67±5.16
	c	6	122.00±2.10	121.67±3.08

a: Experimental group, b: Comparison group, c: Control group

This indicates that sustained attention increased from pre- to post-intervention in both the experimental and comparison groups, while it decreased in the control group. Results from a repeated measures two-way ANOVA to examine the differences in sustained attention between groups and at pre- and post-measurement points are shown in Table 18.

Table 18. Two-way ANOVA for pre and post sustained attention by group

Source of variance	Sum of squares	*df*	*MS*	*F*	*p*	Contrast
Group	3257.17	2	1628.58	117.40	.000	a>b>c
error	208.08	15	13.87			
measurement time point	2791.36	1	2791.36	352.59	.000	
Group×time point	3339.39	2	1669.69	210.91	.000	
Error (time point)	118.75	15	7.92			

a: Experimental group, b: Comparison group, c: Control group

The results show that there were significant differences in sustained attention across the different groups (F=117.40, p=.000). Additionally, there were significant differences in sustained attention at different measurement points within each group (F=352.59, p=.000), and there was an interaction effect between the groups and measurement points regarding sustained attention (F=210.91, p=.000). Furthermore, the post-hoc comparisons revealed that the experimental group had the highest levels of sustained attention compared to the comparison and control groups.

4. Discussion

4.1 Brain Function Index

The Self-Regulation Quotient (SRQ) is a fundamental measure of brain health and activity. The brain autonomously regulates three states—rest, attention, and concentration—while controlling its activity rhythm. The SRQ quantifies the brain's self-regulation ability across these three fundamental states[21].

In this study, the SRQ showed the greatest change in the experimental group, with significant increases observed in all groups. This result is consistent with previous studies[9,22], suggesting that brain development programs enhance self-regulation abilities and maintain the brain in a positive and efficient state, aiding in learning and self-control. Additionally, it aligns with research by Choi et al.[2], which found that physical activities help ADHD students manage various cognitive functions and self-regulation, supporting the effectiveness of complex attention training programs.

ADHD students often experience inefficiencies that impact learning and interpersonal relationships[2]. The highest self-regulation score in the experimental group, as seen in this study, suggests that the 8-week compound attention program effectively improved self-control and sustained attention, which is consistent with Choi et al.[2]. This suggests that the combined program of EEG and target-related physical activities positively impacts the self-regulation quotient.

Attention Quotient (AQ) measures brain alertness and resistance to disease and stress. A higher AQ indicates clearer brain alertness, better learning abilities, and immune function [24], whereas a lower AQ may indicate decreased attention, resistance, and potential cognitive decline[21].

In this study, the AQ was highest in the experimental group. Significant differences were found among groups, with no significant difference between the experimental and comparison groups. This result aligns with research by Choi et al.[2], which found that ADHD students' inability to focus was related to executive function, and supports findings that physical activities alone positively influence brain function. Although no significant difference was observed between the experimental and comparison groups statistically, the experimental group had the highest AQ.

The results align with studies integrating sports activities and target challenge activities[16,24], suggesting that combining EEG with target-related physical activities enhances ADHD students' performance. Kim[23] and others suggest that an extended training period could yield even better results. The limited number of participants might explain the lack of significant statistical differences between groups. The Brain Quotient (BQ) is a comprehensive evaluation of brain function based on all indices. It is not absolute but can be developed

through personal effort.

In this study, BQ increased in all groups, with the experimental group showing the highest scores compared to the comparison and control groups. This result is consistent with Yoo[21], Kim[23], Choi et al.[2], and Medina et al.[25], indicating that attention and physical activity programs positively impact cognitive function and attention, improving the BQ.

However, this contradicts, who found that shorter training periods might not show significant differences. This suggests that complex attention programs are more effective than single activity programs.

4.2 Attention

In the attention tests, selective attention increased in the experimental and comparison groups but slightly decreased in the control group. Significant differences were observed between groups. This result contrasts with Shin[16] but aligns with Shin et al.[1], indicating that compound attention programs and target-related physical activities positively impact selective attention in ADHD students.

Self-control is crucial for managing distractions and solving tasks efficiently[16], and the study showed increased self-control in the experimental and comparison groups, with no change in the control group. These findings align with research on martial arts[26], swimming [27], and other activities [16].

Self-regulation allows appropriate responses to environmental demands, adjusting the intensity and frequency of behaviors[28,29]. This study suggests that compound attention programs positively impact self-control, consistent with research on physical activities' effects on ADHD.

For sustained attention, the experimental and comparison groups showed increased results, while the control group decreased. This finding aligns with Shin et al.[1], and Choi et al.[2], indicating that compound attention programs and target-related physical activities positively affect sustained attention.

However, this contrasts with Shin[16], who found no difference due to learning experiences. The significant statistical differences in this study suggest that compound attention programs are more effective than simple target-related physical activities.

5. Conclusion and Recommendations

This study investigated the effects of a compound attention program on ADHD students' brain function indices and attention. The program, which included EEG-based attention training and target-related physical activities (e.g., Tuho, darts, bowling), was applied for 8 weeks to the experimental group, a target-related physical activities group, and a no-treatment control group. The findings are as follows:

The compound attention program showed positive effects on self-regulation, attention, and brain function indices compared to target-related physical activities and no-treatment groups. The program also positively impacted selective attention, self-control, and sustained attention. Based on these findings, the study has the following recommendations:

Future research should use high-resolution imaging techniques like functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) for a more scientific approach. Additional methods, such as interviews, counseling, and observations, should be used to compare attention and behavior changes. Increasing the sample size in future studies could provide more robust results.

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