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ORIGINAL ARTICLE

Effects of Play Attention Neurofeedback Training on Cognitive Functions and Lifting Performance in Young Elite Weightlifters

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ABSTRACT

This study examined the effects of Play Attention-based neurofeedback training (NFT) on attention-related cognitive functions and total lifting performance in young elite weightlifters. Using a quasi-experimental pre-test-post-test control group design, ten athletes aged 13-14 years were assigned to an experimental group (n=5) or a control group (n=5). The experimental group completed a 20-session NFT program over three months in addition to routine weightlifting training, while the control group continued regular training only. Cognitive performance was assessed through task-based metrics provided by the Play Attention system, targeting sustained attention, visual tracking, task completion, memory, and discrimination. Athletic performance was evaluated using total lifting performance (kg), calculated as the combined sum of snatch and clean & jerk lifts. Statistical analyses included paired samples t-tests, independent samples t-tests with Welch correction, effect size calculations (Cohen's d), and normality testing. Results revealed that the experimental group demonstrated significant pre-post improvements in total lifting performance ($p < 0.01$), accompanied by very large effect sizes (Cohen's d > 2.0), whereas the control group showed smaller gains. Mean total lifting performance increased by approximately 35% in the experimental group, exceeding the control group's improvements by 16-20%. Cognitive outcomes showed consistent improvements across all assessed domains, while body weight changes remained minimal and comparable between groups, indicating that performance gains were largely independent of physiological growth. These findings suggest that Play Attention-based NFT may serve as an effective supplementary training modality for enhancing attentional control and technical performance in young elite weightlifters. Further studies with larger samples are warranted to confirm these results.

Keywords: Neurofeedback training, play attention, sports performance, weightlifting ,

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INTRODUCTION

Attention is a core executive function that enables individuals to selectively process relevant stimuli, allocate cognitive resources efficiently, and sustain goal-directed behavior. Since William James' (1890) foundational description, attention has been conceptualized as a multi-component construct encompassing sustained, selective, and divided attention, closely interacting with higher-order executive processes such as inhibition, planning, and cognitive flexibility (Mirsky et al., 1991; Posner & Petersen, 1990; Diamond, 2013).

In sport settings, attentional control and executive functioning are recognized as critical determinants of high-level performance. Empirical evidence indicates that elite athletes outperform non-athletes in measures of attentional flexibility, decision-making, and cognitive control, and that these abilities are predictive of competitive success (Voss et al., 2010; Vestberg et al., 2012). Such cognitive demands are particularly pronounced in closed-skill sports, where environmental conditions are relatively stable but technical precision and timing accuracy are paramount.

Olympic weightlifting represents a prototypical closed-skill sport requiring maximal force production combined with highly precise motor execution. Successful performance in the snatch and clean & jerk depends not only on physical strength and technical proficiency but also on sustained attention, visuomotor coordination, and effective error monitoring (Schmidt & Lee, 2011). Previous studies have demonstrated that attentional focus strategies and executive control directly influence bar-path consistency, lifting efficiency, and overall performance outcomes in weightlifting and related strength sports (McGuigan & Winchester, 2008; Wulf, 2013).

In recent years, neurofeedback-based cognitive training has gained increasing attention as a supplementary method for enhancing attentional regulation and executive functioning. EEG-based neurofeedback interventions have been shown to modulate neural networks associated with attention and sensorimotor integration, leading to improvements in cognitive performance (Enriquez-Geppert et al., 2017; Cheron et al., 2016). Systematic reviews and meta-analyses further indicate that neurofeedback training can produce moderate-to-large effects on sports performance, particularly in disciplines requiring high levels of technical accuracy and attentional stability (Mirifar et al., 2017; Gong et al., 2023; Xiang et al., 2024).

Despite this growing body of evidence, the existing literature has largely focused on team sports or general athletic populations. Experimental research examining neurofeedback interventions in Olympic weightlifting, especially among young elite athletes, remains scarce. Moreover, few studies have evaluated performance outcomes using total lifting performance, the primary criterion determining competitive success in weightlifting. This gap limits the understanding of how neurofeedback-assisted attention training may contribute to performance enhancement in technically demanding closed-skill sports. Therefore, the purpose of the present study was to investigate the effects of Play Attention–based neurofeedback training on attention-related cognitive functions and total lifting performance in young elite weightlifters. By focusing on statistically derived performance outcomes and addressing a clearly defined gap in the literature, this study aims to contribute to the growing field of neurotechnology-supported performance enhancement in sport science.

Material and Methods

Research Design

This study employed a quasi-experimental pre-test-post-test control group design to examine the effects of Play Attention-based neurofeedback training on total lifting performance in young elite weightlifters.

Participants

Ten elite youth weightlifters (aged 13-14 years) participated in the study and were assigned to an experimental group (n=5) or a control group (n=5). All participants were actively competing and medically cleared.

Intervention

The experimental group completed a Play Attention neurofeedback training program consisting of 20 individual sessions over three months (two sessions per week, 30-35 minutes per session), in addition to regular weightlifting training. The program targeted sustained attention, visual tracking, task completion, memory, and discrimination through EEG-based real-time feedback. The control group continued routine training only (ADD Centres, 2021; Demos, 2005).

Measurements

Performance was evaluated using total lifting performance (kg), calculated as the sum of snatch and clean & jerk lifts, assessed at pre-test and post-test. Cognitive performance was monitored using task-based metrics provided by the Play Attention system

Statistical Analysis

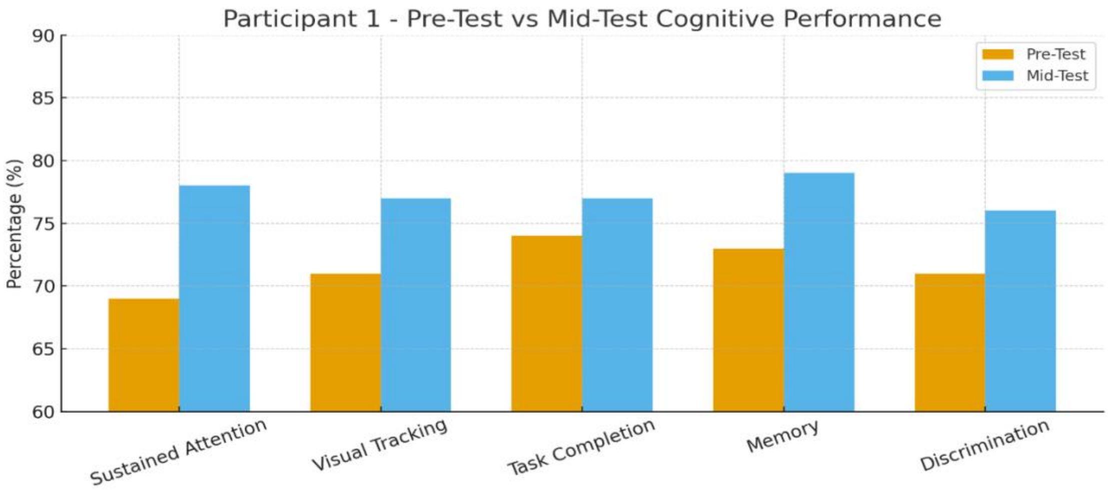
Data were analyzed using paired samples t-tests for within-group comparisons and independent samples t-tests (Welch correction) for between-group differences. Cohen's d was calculated to determine effect sizes. Normality was assessed using the Shapiro-Wilk test, and significance was set at $p < 0.05$.

Ethics

This research was conducted with the approval of the Tokat Gaziosmanpaşa University Social and Human Sciences Research Ethics Committee, in line with the official correspondence dated 22 July 2024 (No. 452963).

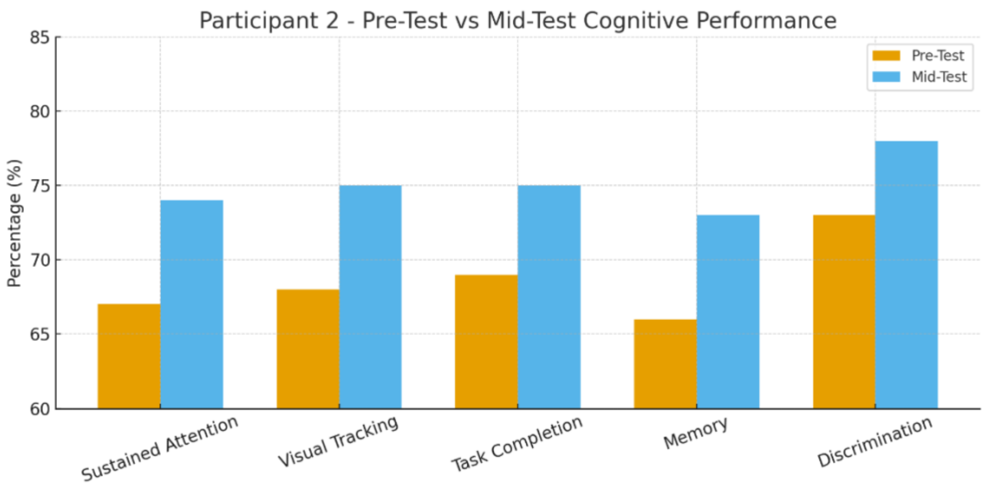
Results

Figure 1. Participant 1 Play Attention Pre-Test and Post-Test Scores



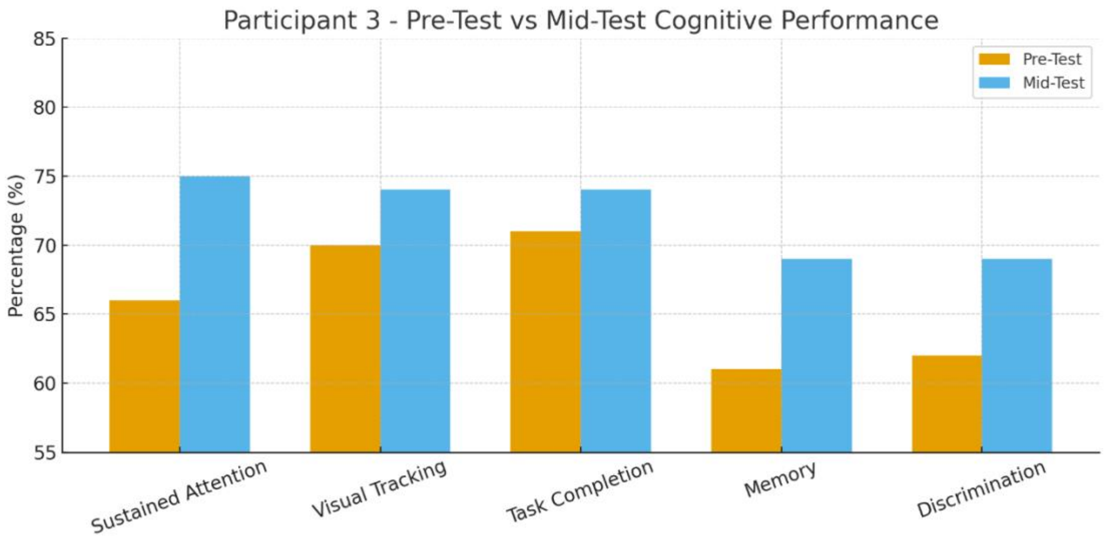
In Figure 1, Participant 1's The sustained attention score increased from 69% in the pre-test to 78% in the mid-test. The visual tracking score increased from 71% to 77%. The task completion score improved from 74% to 77%. The memory score increased from 73% to 79%. The discrimination score increased from 71% to 76%.

Figure 2: Participant 2 Play Attention Pre-Test and Post-Test Scores



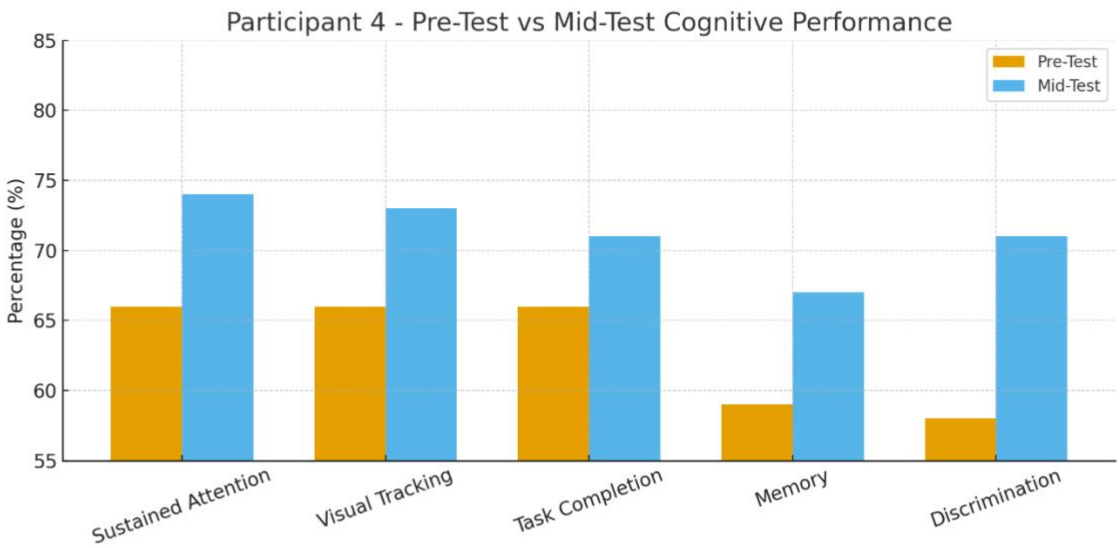
In Figure 2, Participant 2's The sustained attention score increased from 67% in the pre-test to 74% in the mid-test. The visual tracking score increased from 68% to 75%. The task completion score improved from 69% to 75%. The memory score increased from 66% to 73%. The discrimination score increased from 73% to 78%.

Figure 3: Participant 3 Play Attention Pre-Test and Post-Test Scores



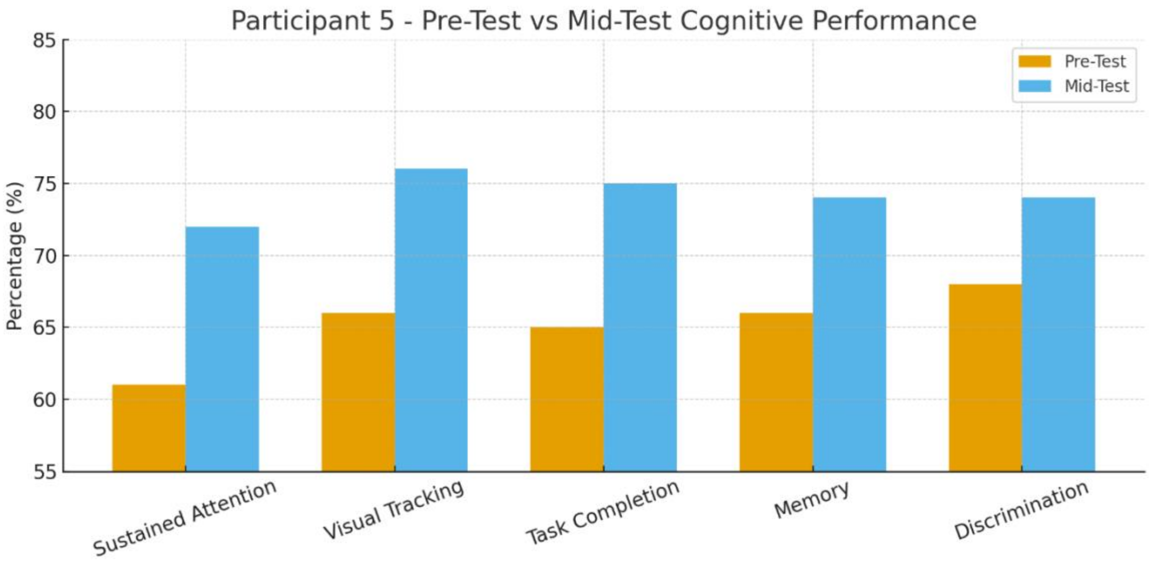
In Figure 3, Participant 3's The sustained attention score increased from **66% in the pre-test** to **75% in the mid-test**. The visual tracking score rose from **70%** to **74%**. The task completion score improved from **71%** to **74%**. The memory score increased from **61%** to **69%**. The discrimination score increased from **62%** to **69%**.

Figure 4: Participant 4 Play Attention Pre-Test and Post-Test Scores



In Figure 4, Participant 4's sustained attention score increased from 66% in the pre-test to 74% in the mid-test.The visual tracking score rose from 66% to 73%.The task completion score improved from 66% to 71%.The memory score increased from 59% to 67%.The discrimination score increased from 58% to 71%.

Figure 5: Participant 5 Play Attention Pre-Test and Post-Test Scores



In Figure 5, Participant 5's sustained attention score increased from 61% in the pre-test to 72% in the mid-test. The visual tracking score improved from 66% to 76%. The task completion score increased from 65% to 75%. The memory score rose from 66% to 74%. The discrimination score increased from 68% to 74%.

Table 1. Pre-Test and Post-Test Weight Lifting Measurements and Percent Changes of the Research Group

Participant	Pre Total (kg)	Post Total (kg)	% Change
Participant 1	98	133	35.7
Participant 2	100	140	40.0
Participant 3	145	200	37.9
Participant 4	133	178	33.8
Participant 5	98	127	29.6

Total lifted weight was calculated as the sum of snatch and clean & jerk performances for each participant. Percentage change values represent the relative increase from pre-test to post-test performance and were calculated by comparing post-test values to baseline measurements. In the experimental group, total lifted weight increased from 98–145 kg at pre-test to 127–200 kg at post-test, corresponding to percentage increases ranging from 29.6% to 40.0%. All numerical values were carefully reviewed and corrected where necessary to ensure internal consistency and accurate representation of performance changes prior to statistical analysis.

Table 2. Pre-Test And Post-Test Weight Lifting Measurements And Percent Changes Of The Control Group

Participant	Pre Total (kg)	Post Total (kg)	% Change
Participant 1	110	145	31.8
Participant 2	116	146	25.8

Participant 3	120	148	23.3
Participant 4	115	144	25.0
Participant 5	83	109	31.3

Pre-test and post-test total lifting performance values represent the combined sum of snatch and clean & jerk performances for each participant. Percentage change values indicate the proportional increase from pre-test to post-test total lifting performance and were calculated relative to baseline measurements. In the control group, total lifting performance increased from 83–120 kg at pre-test to 109–148 kg at post-test, with percentage changes ranging from 23.3% to 31.8%. All numerical values were reviewed and verified for internal consistency prior to analysis.

Table 3. Age and Body Weight Data of Participants

Experimental Group	Age	Pre-Test Body Weight (kg)	Post-Test Body Weight (kg)	Change (%)
Participant1	14	72	75	4.2
Participant2	13	73	75	2.7
Participant3	13	78	80	2.5
Participant4	14	73	75	2.7
Participant5	13	56	58	3.5
Control Group	Age	Pre-Test Body Weight (kg)	Post-Test Body Weight (kg)	Change (%)
Participant1	14	55	57	3.6
Participant2	13	58	60	3.5
Participant3	13	64	67	4.6
Participant4	14	77	78	1.3
Participant5	14	70	70	0

According to Table 3, the athletes in the experimental group showed low but consistent increases in body weight between the pre-test and post-test measurements. Participant 1's body weight increased by 4.2%, while Participants 2 and 4 showed changes of 2.7%. Participant 3's weight increased by 2.5%, and Participant 5's by 3.5%. These results indicate that weight gains in the experimental group were within a similar range and at a low level, suggesting that the observed performance improvements were largely independent of changes in body mass. In the control group, body weight changes were also low but varied more between participants. Participant 1's body weight increased by 3.6%, and Participant 2's by 3.5%. Participant 3 showed the highest weight gain in the control group at 4.6%, while Participant 4 increased by only 1.3%. No change in body weight was observed for Participant 5.

Table 4. Summary of Statistical Analyses for Pre-Post Comparisons and Group Differences

Analysis Type	Group	Test	Statistic	p	Effect Size
Normality	Experimental	Shapiro-Wilk	W = 0.94	>0.05	Normal
Normality	Control	Shapiro-Wilk	W = 0.91	>0.05	Normal
Pre-Post Comparison	Experimental	Paired samples t-test	t = 7.53	0.002	Cohen's d = 3.37
Pre-Post Comparison	Control	Paired samples t-test	t = 4.41	0.012	Cohen's d = 1.97
Group Comparison	Experimental vs Control	Independent samples t-test	t = 3.25	0.013	Cohen's d = 2.05

Table 4 peresents normality of change scores (post-test minus pre-test values) was assessed using the Shapiro-Wilk test. As normality assumptions were met, parametric statistical procedures were applied. Within-group pre-post differences were examined using paired samples t-tests, whereas between-group differences were analyzed using independent samples t-tests on change scores (Welch's correction applied due to small sample size). Effect sizes were calculated using Cohen's d and interpreted according to conventional criteria (0.20 = small, 0.50 = medium, 0.80 = large).

Discussion

The findings of the present study provide strong empirical support for the association between Play Attention-based neurofeedback training (NFT) and improvements in both cognitive functioning and total lifting performance in young elite weightlifters. Statistical analyses revealed that the experimental group exhibited a significant increase in total lifted weight from pre-test to post-test ($p < 0.01$), accompanied by a very large effect size (Cohen's d>2.0). In contrast, although the control group demonstrated moderate performance gains, these improvements were substantially smaller in magnitude, indicating that routine training alone does not fully account for the observed performance enhancement.

Cognitive data derived from the Play Attention system showed consistent improvements across all assessed domains, including sustained attention (10-18%), visual tracking (4-10%), task completion (4-15%), memory (8-13%), and discrimination (6-22%). Importantly, these cognitive gains coincided with pronounced increases in lifting performance, with the experimental group achieving improvements of approximately +35% in total lifting performance, exceeding the control group's gains by nearly 16-20%. Given that changes in body weight were minimal and comparable between groups (approximately 2.5-4.6%), the performance improvements observed in the experimental group appear to be largely independent of physiological growth or body mass adaptations.

These findings are consistent with previous research emphasizing the central role of attentional and executive functions in closed-skill sports that demand precision, timing accuracy, and stable motor execution (Wulf, 2013; McGuigan & Winchester, 2008). Neurofeedback training has been shown to enhance neural efficiency and attentional regulation, thereby supporting more effective sensorimotor integration during complex motor tasks (Cheron et al., 2016; Enriquez-Geppert et al., 2017). Systematic reviews and meta-analyses further demonstrate that NFT produces moderate-to-large effects on sports performance, particularly in disciplines characterized by high technical demands (Mirifar et al., 2017; Gong et al., 2023; Xiang et al., 2024).

The substantial improvement observed in snatch performance aligns with evidence indicating that NFT enhances visuomotor timing, error monitoring, and movement consistency factors that are critical for bar-path control and successful lift execution. Similarly, gains in clean & jerk performance may reflect improvements in working memory and task-switching ability, which are essential for managing the multi-phase structure of this lift (Vestberg et al., 2012). Together, these results reinforce the view that attentional control and executive functioning are not merely supportive elements but key determinants of high-level performance in skill-dependent strength sports.

From a developmental perspective, the age range of the participants (13-14 years) represents a period of heightened neural plasticity, particularly within prefrontal networks associated with executive control and attentional regulation (Diamond, 2013; Arnsten, 2009). This developmental sensitivity may partly explain the consistent and uniform improvements observed across both cognitive and performance variables in the experimental group. Similar patterns have been reported in youth populations undergoing neurofeedback interventions, where attentional gains appear more pronounced than in adult samples (Arns et al., 2009; Barker & Cook, 2005).

Taken together, the present findings suggest that NFT via the Play Attention system functions not merely as a psychological support tool but as a performance-relevant supplementary training modality with measurable effects on cognitive control and technical execution. The convergence of statistically significant performance gains, large effect sizes, and theoretically grounded cognitive improvements supports the integration of neurofeedback-based cognitive training into long-term athlete development models. In line with recent meta-analytic evidence (Gong et al., 2023; Xiang et al., 2024), neurotechnology-assisted interventions may contribute meaningfully to performance optimization in elite weightlifting, particularly during critical developmental stages.

Conclusions

This study suggests that Play Attention-based neurofeedback training is associated with meaningful improvements in total lifting performance and attention-related cognitive functions in young elite weightlifters. Compared with the control group, the experimental group demonstrated significantly greater pre-post gains in total lifted weight, supported by large effect sizes and strong performance consistency, while body weight changes remained minimal.

Improvements observed in sustained attention, visual tracking, task completion, memory, and discrimination provide a cognitive basis for the enhanced technical performance reflected in total lifting outcomes. Given the high attentional and coordinative demands of Olympic weightlifting, these findings indicate that neurofeedback training may serve as a valuable supplementary intervention alongside traditional strength and technical training.

Although the small sample size limits generalizability, the consistency of cognitive and performance gains supports further investigation of neurofeedback-assisted training within youth elite sport development programs.

Author Contributions:

Conceptualization, S.S.; methodology, S.S.; formal analysis, S.S. and H.E.M.; investigation, S.S.; data curation, S.S. and H.E.M.writing—original draft preparation, S.S.; writing—review and editing, S.S. and H.E.M.

Informed Consent Statement:

The research was conducted in line with the Declaration of Helsinki. Informed consent was obtained from all subjects involved in the study.

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Conflicts of Interest:

The authors declare no conflict of interest.

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