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The Effect of Cognitive Training Program on Badminton Skills and Cognitive Ability in Secondary School Students

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Abstract

Background and Aim: Cognitive ability was indeed a key component for elite badminton athletes, as evidenced by multiple studies highlighting various cognitive skills essential for high-level performance in the sport. The research objective of this study was to study the effect of the cognitive training program on badminton skills and to compare the mean values of badminton skills between and within the experimental group.

Materials and Methods: This study was quasi-experimental research, and the participants on 24 badminton players in Zhixin secondary School in Guangzhou who were purposively sampled and systematically with badminton skills ranging to the experimental and control groups. The experimental group was conducted for eight weeks, three days/week, and 120 minutes/day of a cognitive training program. In addition, the experimental group also conducted a badminton training program, with badminton skills such as pace, serve, smash, drop shot, drive, and clear. The cognitive ability and badminton skills were examined on the pre-test, mid-test, and post-test. Data analysis was calculated on mean and standard deviation, t-test independent, one-way ANOVA repeated measurement, Bonferroni post hoc, significance difference set at p<.05.

Results: The results found that (1) In comparing the experimental and control groups, all variables related to badminton skills showed significant differences (*p<.05). (2) When comparing experimental and control groups, the cognitive ability test showed a significant difference (*p<.05); however, the mental rotation test did not. (3) There were significant differences (*P<.05) in badminton skills and cognitive ability across experimental groups at the pretest, mid-test, and post-test. (4) The cognitive training program was strong in content validity (IOC =.80).

Conclusion: The effectiveness of the cognitive training program was demonstrated by the study's conclusion, which showed that it significantly enhanced the experimental group's cognitive and badminton skills. The program also demonstrated strong content validity, even though mental rotation skills were unaffected.

Keywords: Badminton skills, Cognitive training, Secondary school player

Introduction

The development of youth athletes was indeed a crucial foundation for the advancement of national sports. This was because the formative years of adolescence were pivotal for physical, psychological, and social development, which were essential for nurturing future elite athletes. The integration of sports and health, as well as the focus on nutrition and training, play significant roles in this developmental phase. The following sections elaborate on these aspects. Integration of Sports and Health was vital for the healthy development of youth athletes, which in turn supports the transformation of a nation into a sports power. China's success in producing world-class badminton athletes is attributed to a systematic and sustainable approach to athlete development, which integrates multiple factors. Key elements include a focus on physical conditioning, technical skills, tactical understanding, and psychological resilience, as identified in systematic reviews of international badminton performance factors (Ihsan et al., 2024).

The development of youth badminton athletes to excellence involves a multifaceted approach that integrates physical, psychological, and strategic elements. Key components include anthropometric and physical performance benchmarks, such as explosive power, flexibility, speed, and endurance, which were critical for distinguishing between different skill levels among youth players (Robertson-Martens et al., 2022). Psychological traits, particularly perfectionism, also play a significant role, with elite players often exhibiting higher levels of this trait. Additionally, the morpho-functional conditions, which evolve through

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different training stages, highlight the importance of somatic features and coordination abilities in early training, transitioning to speed and strength in later stages (Jaworski & Żak, 2015). Performance enhancement strategies further underscore the importance of integrating physical training, game tactics, nutritional interventions, recovery strategies, and psychological approaches to optimize athlete performance (Karyono et al., 2024).

The majority of reports focus on how physical training and psychological fitness influence sports skills, but brain training has not yet had a significant impact on sports skills, so it was unclear whether brain training would affect skills or not. Cognitive abilities play an important role in enhancing badminton skills to high levels due to several advantages. Elite badminton players exhibit superior reaction times and inhibitory control, which are essential cognitive components for high-level performance. The Badminton Reaction Inhibition Test (BRIT) demonstrated that elite players had significantly better badminton-specific reaction times compared to non-elite players, indicating the importance of cognitive skills in distinguishing skill levels (Water et al., 2017). Furthermore, psychological characteristics such as perfectionism, which is linked to cognitive processes, were significantly higher in elite youth badminton players, suggesting that cognitive traits contribute to talent identification and development (Robertson-Martens et al., 2022). The integration of neuroscience into sports performance research highlights the role of cognitive executive functions in predicting sporting success, emphasizing the need for cognitive training in sports (Kilger & Blomberg, 2020). Perceptual-cognitive skills training, which focuses on anticipation and decision-making, is crucial for transferring learned skills to real-life performance, further underscoring the importance of cognitive training in sports (Broadbent et al., 2015). Additionally, studies in related sports, such as tennis, show that cognitively engaging exercises improve executive functions like inhibitory control and working memory, which were transferable to badminton, enhancing overall performance (Ishihara et al., 2017). These findings collectively suggest that cognitive abilities, through targeted training and inherent psychological traits, significantly contribute to the advancement of badminton skills.

The development of brain skills such as information processing, executive functions, cognitive flexibility, and inhibitory control was crucial for enhancing athletic performance in Thai youth soccer players (Yongtawee et al, 2020). Executive functions (EFs), which include working memory, inhibition, and cognitive flexibility, were integral to soccer performance, as they influence decision-making and tactical execution on the field (Heilmann et al., 2022). Cognitive training interventions, such as smartphone games, have been explored to improve these functions, but results indicate limited efficacy in enhancing EFs among youth soccer players, suggesting the need for more domain-specific approaches (Heilmann et al., 2022).

In evaluating athlete performance in badminton, mental performance was a critical component alongside physical fitness and technical skills. Mental toughness, which includes self-confidence, attention control, and motivation, is particularly significant, with studies indicating that female badminton players often exhibit higher levels of these attributes compared to their male counterparts, potentially contributing to their success in competitions. Additionally, working memory plays a vital role in badminton, as athletes must process and react to rapidly changing situations. Research using functional near-infrared spectroscopy (fNIRS) has shown that long-term professional training in badminton enhances brain activation in areas associated with working memory, such as the left frontal-parietal attention network and the prefrontal cortex, which are crucial for quick decision-making and perception during matches.

From the above, the researcher had doubts about the development of youth badminton players to be ready to become top athletes. Therefore, the researcher is interested in studying the effects of cognitive training on badminton skills or not.

Objectives

The objective of this study was as follows:

1. To study the effect of a cognitive training program on badminton skills and cognitive ability.

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2. To compare the badminton skills and cognitive ability between the experimental and control groups and within the experimental group.

3. To develop a cognitive training program to improve badminton skills and cognitive ability for secondary school students

Literature review

Cognitive ability and badminton skills

Cognitive abilities play a crucial role in sports, influencing both performance and development across various disciplines. In primary school sports, such as volleyball, cognitive abilities like spatialization and IQ were directly proportional to situational motor skills, indicating that higher cognitive abilities can lead to better performance in sports that require coordination and movement precision (Bajrami et al., 2022). This relationship is further supported by findings in youth volleyball, where basic cognitive functions, including reaction time and executive control, correlate positively with sport-specific physical performance, suggesting that athletes with superior cognitive skills tend to excel in their respective sports (Trecroci et al., 2021). Additionally, perceptual-cognitive abilities, which encompass skills like multiple-object tracking, were found to be superior in young athletes compared to non-athletes, with notable gender differences in performance patterns, highlighting the importance of these abilities in sports engagement during adolescence (Legault et al., 2022). In team sports, cognitive load management is essential for optimizing performance and preventing injuries, although research on cognitive load indicators remains limited (Fuster et al., 2021). Moreover, in sports like soccer, cognitive functions such as attention and processing speed were linked to game performance, underscoring the significance of cognitive skills in strategic and fast-paced environments (Sabarit et al., 2020). The development of cognitive abilities is also emphasized in basketball training for young players, where exercises are designed to enhance both coordination and cognitive skills, reflecting the intertwined nature of these abilities in sports (Zaichenko & Kozina, 2022). Furthermore, sports practice during childhood is associated with improvements in cognitive flexibility and processing speed, demonstrating the potential of sports to stimulate cognitive development (Mazzoccante et al., 2019).

Cognitive ability and badminton skills

Cognitive abilities play a significant role in enhancing the sports skills of elite badminton players, as evidenced by various studies. Cognitive executive functions, which include skills such as attention, working memory, and cognitive flexibility, were crucial in predicting sporting success, as they enable athletes to process information quickly and make strategic decisions during gameplay (Kilger & Blomberg, 2020). In badminton, the ability to perform dual tasks, which involve both motor skills and cognitive performance, was essential. This was because players must maintain postural control while responding to cognitive cues, such as anticipating the opponent's moves and reacting swiftly to the shuttlecock's trajectory (Şimşek et al., 2023). Badminton training has been shown to improve visuomotor integration, a cognitive skill that involves visual tracking and temporal prediction, which is critical given the high-speed nature of the sport (Chen et al., 2022). Furthermore, cognitive performance, including reaction time and inhibition control, was a distinguishing factor between national and non-national level athletes, highlighting the importance of cognitive training in achieving elite status (Praja et al., 2020). Mental toughness, another cognitive aspect, is also vital for elite performance, as it helps athletes manage stress and maintain focus under pressure (Torma & Balogh, 2021; Trika, 2019). Mental training programs, which often include techniques such as imagery and relaxation, have been shown to enhance mental skills like concentration and motivation, further supporting performance improvements in racket sports like badminton (Cece et al., 2020).

Cognitive abilities were crucial for success in various sports, influencing performance, skill development, and strategic decision-making, with benefits extending to improved cognitive development and mental toughness.

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Conceptual Framework

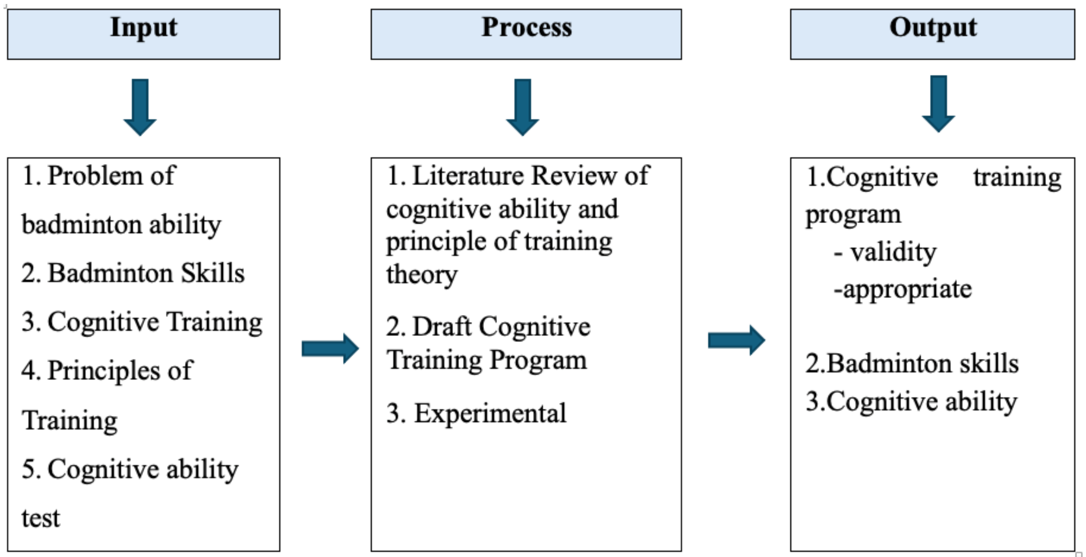

Figure 1: Conceptual Framework

Methodology

This study was quasi-experimental research that had passed the ethics review of human research from the Human Research Review Committee, Bangkokthonburi University, license number 2567/127(14), date of certification 31 July 2024.

Population and sample

The population was 24 badminton players (male=18, female 6), aged 12 - 15 years old, in the academic year 2024, at Zhixin Secondary School in Guangzhou, Guangdong Province, China.

The Sample was a propulsive sampling that systematic method with badminton skills ranging dividing each group with 12 players (male, female=3), a control group, and an experimental group, with badminton skill tests by a systematic method.

Inclusion criteria are as follows:

1. Participants were students of the badminton team at Guangzhou Zhixin Secondary School, aged 12-15 years old.
2. Participants must be cleared by a doctor to ensure they do not have any injuries.
3. All participants must voluntarily sign a consent form to participate in the study.

Exclusion Criteria are as follows:

1. Participated in the experiment for more than 80% of the training duration.
2. They were injured during the experiment, which prevented them from continuing to participate in the experiment.
3. Subjects apply to leave the research project.

Research design

The quasi-experimental research was conducted in this study.

Control group	O1	T1	O3	T1	O5
Experimental group	O2	T2	O4	T2	O6

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Note T_1= Regular training program, T_2= Cognitive training program, O_1= pre-test of control group, before training, O_2= pre-test of experimental, before training, O_3= Mid-test of control group after training 4th week, O_4= Mid-test of experimental group after training 4th week, O_5 = Post-test of control group after training 8th week, O_6= post-test of experimental group after training 8th week

Research instrument

In this study following three primary research instruments will be utilized:

1**. Cognitive Training Program:** A program developed by the researcher that included training components, cognitive ability training, and badminton skills; an 8-week training period; three days a week (MWF); and 120-minute sessions.

Finding quality tools with three experts to assess the content validity was evaluated with an index of item objective congruence (IOC) of .80, and the training program was adapted with exercise drills, and training intensity was tested out by three and five of the trial subjects.

2. Badminton Skill Test: In the assessment of badminton skills, to ensure the authority and standardization of the test, the pace test, serve test, smash test, drop shot test, drive test, and clear test are conducted.

3. Cognitive ability test: consists of Simple reaction time test**,** Selection Reaction Time test**,** Connection test TMT-A& test TMT-B**,** Fanker test**,** Graphic design ability test**,** Mental rotation test, and Spatial visualization test. (Department of Physical Education, 2020).

Data collection

The researcher collected data as follows:

1. The researcher held a meeting with the sample group and research assistants to explain the research project procedures, including training schedules, tests, training uniforms, training dates, locations, and other agreements.
2. Data Collection before the training program was conducted with a pretest, including the characteristics, badminton skills, and cognitive ability.
3. The cognitive training program was conducted for 8 weeks in the experimental group and the badminton training program in the control group, then data were collected with a mid-test after training 4th Week and a post-test after training in the 8th week.
4. All test data were compiled and analyzed for further statistical values.

Data analysis

The researchers analyzed the data of the badminton skills test and cognitive ability test, and comparisons between the experimental and the control groups and within the experimental group.

Statistic

The statistics were used in this as follows:

1. Mean and standard deviation
2. t-test of independence
3. One-way ANOVA repeated measurement and Bonferroni post hoc.
4. Set the significance level at 0.05

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Results

The results of the study were to answer the research hypothesis as follows:
1. The badminton skills of the experimental group were better than those of the control group.
2. The badminton skills within the experimental group after training were better than before training.

Table 1: Characteristics of the sample groups

variable	Experimental group (n=12)	Control group (n=12)
	M±SD	M±SD
Age (years)	14.70±0.80	14.50±0.70
Weight (kg)	55.20±5.10	56.30±4.90
Height (cm)	164.50±6.20	163.90±5.80
BMI	20.40±1.10	20.90±1.00
Training experiences (years)	3.10±1.20	2.90±1.10

Form Table 1 found that the mean and standard deviation for each variable in both groups were as follows:

Experimental Group (n = 12), age: 14.70 ± 0.80 years, weight: 55.20 ± 5.10 kg, height: 164.50 ± 6.20 cm, BMI: 20.40 ± 1.10, and badminton training years: 3.10 ± 1.20 years.

Control Group (n = 12), age: 14.50 ± 0.70 years, weight: 56.30 ± 4.90 kg, height: 163.90 ± 5.80 cm, BMI: 20.90 ± 1.00, and badminton training years: 2.90 ± 1.10 years.

Table 2: Mean and standard deviation of the badminton skill test in the experimental group and the control group

Variables	**Experimental Group**			**Control Group**		
	Pre-test	**Mid test**	**Post-test**	**Pre-test**	**Mid test**	**Post-test**
	M+SD	**M+SD**	**M+SD**	**M+SD**	**M+SD**	**M+SD**
Pace Test（sec）	14.17± 0.59	11.88 ± 0.38	8.94 ± 0.30	14.07 ± 0.65	13.24 ± 1.06	10.62 ± 0.31
Serve Test（score）	5.58± 1.08	12.17 ± 1.27	19.00 ± 0.85	5.17 ± 1.27	10.17 ± 0.94	15.92 ± 1.08
Smash Test（score）	4.42± 1.31	11.67 ± 1.07	17.42 ± 0.67	4.00 ± 1.41	8.92 ± 1.73	14.83 ± 1.03
Drop shot Test（score）	5.92 ± 1.38	12.67 ± 1.23	19.83 ± 0.39	5.42 ± 1.08	9.83 ± 0.72	16.75 ± 1.06
Drive Test（score）	5.83 ± 0.94	13.00 ± 1.13	18.17 ± 0.72	5.42 ± 1.31	10.58 ± 1.31	15.75 ± 1.36
Clear Test（score）	6.00 ± 0.74	12.92 ± 1.56	19.58 ± 0.52	5.58 ± 1.08	10.25 ± 1.49	16.92 ± 0.90

From Table 2, the experimental group's scores decreased from 14.17 ± 0.59 on the pre-test to 8.94 ± 0.30 on the post-test, while the control group's scores dropped from 14.07 ± 0.65 to 10.62 ± 0.31. The serve

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test showed a significant increase for the experimental group, from 5.58 ± 1.08 to 19.00 ± 0.85, and a smaller increase for the control group, from 5.17 ± 1.27 to 15.92 ± 1.08. The smash test results for the experimental group rose from 4.42 ± 1.31 to 17.42 ± 0.67, whereas the control group's scores increased from 4.00 ± 1.41 to 14.83 ± 1.03. In the drop shot test, the experimental group's scores improved from 5.92 ± 1.38 to 19.83 ± 0.39, and the control group's scores from 5.42 ± 1.08 to 16.75 ± 1.06. The drive test scores for the experimental group increased from 5.83 ± 0.94 to 18.17 ± 0.72, and the control group's scores from 5.42 ± 1.31 to 15.75 ± 1.36. Finally, the clear test scores for the experimental group went up from 6.00 ± 0.74 to 19.58 ± 0.52, and the control group's scores from 5.58 ± 1.08 to 16.92 ± 0.90. These results suggest that the experimental group showed greater improvement in all tests compared to the control group.

Table 3 Comparison of the mean on the badminton skills pre-test between the experimental group and the control group with an independent t-test.

Variables	Exp. G	Cont. G	95%Confidence Interval of the Difference		t	p
	M±SD	M±SD	lower	Upper		
Pace Test (sec）	14.17±0.59	14.06±0.65	-0.12	0.33	0.86	0.39
Serve Test （score）	5.58±1.08	5.17±1.26	-0.23	1.05	1.24	0.23
Smash Test （score）	4.42±1.31	4.00±1.41	-0.31	1.14	1.14	0.26
Drop shot Test （score）	5.92±1.38	5.42±1.08	-0.11	1.11	1.62	0.11
Drive Test （score）	5.83±0.93	5.42±1.31	-0.16	0.97	1.41	0.16
Clear Test （score）	6.00±0.73	5.58±1.08	-0.18	1.02	1.36	0.18

*P<.05

Table 3 found that all of the badminton skills variables were not significantly different.

Table 4 Comparison of the mean on the badminton skills post-test between the experimental and the control group with an independent t-test.

Variables	Exp. G	Cont. G	95%Confidence Interval of the Difference		t	p
	M±SD	M±SD	lower	Upper		
Pace Test (sec）	8.94±0.29	10.62±0.31	-1.82	-1.56	-21.92	.05*
Serve Test（score）	19.00±0.85	15.92±1.08	2.36	3.20	8.50	.05*
Smash Test（score）	17.42±0.66	14.83±1.03	2.11	3.17	8.24	.05*
Drop shot Test (score）	19.83±0.39	16.75±1.05	2.70	3.46	10.21	.05*
Drive Test（score）	18.17±0.72	15.75±1.35	1.84	3.00	6.89	.05*

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Clear Test（score）	19.58±0.51	16.92±0.90	2.18	3.18	9.07	.05*

*P<.05

Table 4 found that all of the badminton skills variables were significantly different (*p<.05).

Table 5: Means and standard deviation of cognitive ability test in the experimental and control groups

Variables	Experimental Group			Control Group		
	Pre-test	Mid test	Post-test	Pre-test	Mid test	Post-test
	M+SD	M+SD	M+SD	M+SD	M+SD	M+SD
Simple reaction time test (ms)	467.50±14.84	377.50±14.84	287.50±18.02	465.83±13.11	405.83±13.11	342.50±14.22
Selection Reaction Time Test (ms)	415.83±12.40	347.50±14.84	284.50±15.91	415.00±11.68	375.83±13.11	309.17±14.21
Connection test TMT-A and test TMT-B (sec)	58.33±3.78	44.308±1.25	32.04±1.64	56.83±3.45	47.83±0.96	36.33±1.61
Fanker test (ms)	539.17±56.12	412.417±6.35	307.875±22.79	537.08±54.29	426.04±4.32	338.04±12.86
Graphic design ability test (number of graphics)	2.92±0.79	5.25±0.75	11.25±2.05	2.75±0.75	4.67±0.78	8.25±1.60
Mental rotation test (number of graphics)	16.33±0.65	19.92±0.29	24.00±0.01	14.08±0.90	16.17±0.72	18.08±0.79
Spatial visualization test (number of graphics)	17.17±0.94	19.08±0.79	22.25±1.36	14.08±1.17	15.00±1.04	17.00±1.13

Table 5 found that.

Experimental Group: Simple reaction time test (ms), pre-test, mid-test, and post-test (467.50±14.84, 377.50±14.84, and 287.50±18.02), selection reaction time test (ms), pre-test, mid-test, and post-test (415.83±12.40, 347.50±14.84, and 284.50±15.91), connection test tmt-a& test tmt-b (sec), pre-test, mid-test, and post-test (58.33±3.78, 44.31±1.25, and 32.04±1.64), fanker test (ms), pre-test, mid-test, and post-test (539.17±56.12, 412.42±6.35, and 307.88±22.79), graphic design ability test (number of graphics), pre-test, mid-test, and post-test (2.92±0.79, 5.25±0.75, and 11.25±2.05), mental rotation test(number of graphics), pre-test, mid-test, and post-test (16.33±0.65, 19.92±0.29, and 24.00±0.01), and spatial visualization test (number of graphics), pre-test, mid-test, and post-test (17.17±0.94, 19.08±0.79, and 22.25±1.36).

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Control Group: Simple reaction time test (ms), pre-test, mid-test, and post-test (465.83±13.11, 405.83±13.11, and 342.50±14.22), selection reaction time test (ms), pre-test, mid-test, and post-test (415.00±11.68, 375.83±13.11, and 309.17±14.21), connection test tmt-a& test tmt-b (sec), pre-test, mid-test, and post-test (56.83±3.45, 47.83±0.96, and 36.33±1.61), fanker test (ms), pre-test, mid-test, and post-test (537.08±54.29, 426.04±4.32, and 338.04±12.86), graphic design ability test (number of graphics), pre-test, mid-test, and post-test (2.75±0.75, 4.67±0.78, and 8.25±1.60), mental rotation test(number of graphics), pre-test, mid-test, and post-test (14.08±0.90, 16.17±0.72, and 18.08±0.79), and spatial visualization test (number of graphics), pre-test, mid-test, and post-test (14.08±1.17, 15.00±1.04, and 17.00±1.13).

Table 6 Comparison of the mean on the pre-test of cognitive ability between the experimental and the control group with a t-test for independent samples.

Variables	Exp. G	Cont. G	95%Confidence Interval of the Difference		t	p
	M±SD	M±SD	lower	Upper		
Simple reaction time test (ms)	467.50±14.84	465.83±13.11	-7.29	10.63	0.37	0.72
Selection Reaction Time Test (ms)	415.83±12.40	415.00±11.68	-6.34	7.99	0.23	0.82
Connection test TMT-A & test TMT-B (sec)	58.33±3.779	56.833±3.453	-0.46	3.46	1.53	0.13
Fanker test (ms)	539.17±56.12	537.08±54.29	-28.76	32.94	0.14	0.89
Graphic design ability test (Number of graphics)	2.92±0.79	2.75±0.75	-0.29	0.63	0.74	0.46
Mental rotation test (Number of graphics)	16.33±0.65	15.42±0.80	1.47	3.03	5.77	.06
Spatial visualization test (Number of graphics)	17.00±0.94	16.67±1.17	2.12	4.06	6.33	.06

*P<.05

Table 6 found that all pairwise cognitive ability tests showed no significant differences.

Table 7 Comparison of the mean on the post-test of the cognitive ability test between the experimental and the control group with a t-test for independent groups.

Variables	Exp. G	Cont. G	95%Confidence Interval of the Difference		t	p
	M±SD	M±SD	lower	Upper		
Simple reaction time test (ms)	287.50±18.02	342.50±14.22	-66.72	-43.28	-9.35	.05*
Selection Reaction Time Test (ms)	284.50±15.91	309.17±14.21	-33.96	-15.38	-5.47	.05*
Connection test TMT-A & test TMT-B (sec)	32.042±1.644	36.333±1.614	-5.36	-3.22	-8.09	.05*
Fanker test (ms)	307.87±22.79	338.042±12.86	-47.53	-12.81	-3.88	.05*

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Variables	Exp. G	Cont. G	95%Confidence Interval of the Difference		t	p
	M±SD	M±SD	lower	Upper		
Graphic design ability test (Number of graphics)	11.25±2.05	8.25±1.60	1.51	4.49	5.26	.05*
Mental rotation test (Number of graphics)	24.00±0.01	18.08±0.79	5.60	6.24	37.00	.87
Spatial visualization test (Number of graphics)	22.25±1.36	17.00±1.13	4.35	6.15	15.91	.05*

*P<.05

Table 7 found that the cognition ability test had a significant difference (*p<.05), but the mental rotation test had no significant difference.

Table 8 Comparison of the means of badminton skills within the experimental groups by one-way ANOVA with repeated measures and Bonferroni post hoc test

Dependent variables	Test		Bonferroni			M±SD	F	p
			Mean Difference	Std. Error	p			
Pace Test	Pre-test	Mid test	2.29	.18	.05*	14.17±0.59	24280.96	.05*
		Post-test	5.23	.22	.05*			
	Mid test	Pre-test	-2.29	.18	.05*	11.87±0.38		
		Post-test	2.94	.13	.05*			
	Post-test	Pre-test	-5.23	.22	.05*	8.94±0.29		
		Mid test	-2.94	.13	.05*			
Serve Test	Pre-test	Mid test	-6.83	.53	.05*	5.33±0.88	5672.81	.05*
		Post-test	-13.67	.40	.05*			
	Mid test	Pre-test	6.83	.53	.05*	12.17±1.26		
		Post-test	-6.83	.32	.05*			
	Post-test	Pre-test	13.67	.40	.05*	19.00±0.85		
		Mid test	6.83	.32	.05*			
Smash Test	Pre-test	Mid test	-7.250	.48	.05*	4.41±1.31	3445.05	.05*
		Post-test	-13.00	.37	.05*			
	Mid test	Pre-test	7.25	.48	.05*	11.66±1.07		
		Post-test	-5.750	.37	.05*			
	Post-test	Pre-test	13.00	.37	.05*	17.42±0.67		
		Mid test	5.750	.37	.05*			
Dropshot Test	Pre-test	Mid test	-7.08	.38	.05*	5.58±1.08	5185.87	.05*
		Post-test	-14.25	.39	.05*			
	Mid test	Pre-test	7.08	.38	.05*	12.67±1.23		
		Post-test	-7.17	.37	.05*			
	Post-test	Pre-test	14.25	.39	.05*	19.83±0.39		
		Mid test	7.17	.37	.05*			
Drive Test	Pre-test	Mid test	-7.17	.44	.05*	5.83±0.94	8214.00	.05*
		Post-test	-12.33	.40	.05*			

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Dependent variables	Test		Bonferroni Mean Difference	Std. Error	p	M±SD	F	p
	Mid test	Pre-test	7.17	.44	.05*	13.00±1.13		
		Post-test	-5.17	.39	.05*			
	Post-test	Pre-test	12.33	.39	.05*	18.17±0.72		
		Mid test	5.17	.39	.05*			
Clear Test	Pre-test	Mid test	-7.42	.47	.05*	5.50±0.52	5294.67	.05*
		Post-test	-14.08	.26	.05*			
	Mid test	Pre-test	7.42	.47	.05*	12.92±1.56		
		Post-test	-6.67	.43	.05*			
	Post-test	Pre-test	14.08	.26	.05*	19.58±0.51		
		Mid test	6.67	.43	.05*			

*P<.05

Table 8 found that all of the variables had pairwise significant differences (*p<.05).

Table 9 Comparison of the means of cognitive ability test within the experimental groups by one-way ANOVA with repeated measures and Bonferroni post hoc test.

Dependent variables	Test		Bonferroni Mean Difference	Std. Error	p	M±SD	F	p
Simple reaction time	Pre-test	Mid test	74.92	5.24	.05*	467.50±14.84	319.58	.05*
		Post-test	180.00	6.43	.05*			
	Mid test	Pre-test	-74.92	5.237	.05*	392.58±30.02		
		Post-test	105.08	9.21	.05*			
	Post-test	Pre-test	-180.00	6.426	.05*	287.50±18.03		
		Mid test	-105.08	9.21	.05*			
Selection Reaction Time	Pre-test	Mid test	68.33	1.12	.05*	415.83±12.40	427.70	.05*
		Post-test	131.33	5.30	.05*			
	Mid test	Pre-test	-68.33	1.12	.05*	347.50±14.85		
		Post-test	63.00	5.59	.05*			
	Post-test	Pre-test	-131.33	5.30	.05*	284.50±15.91		
		Mid test	-63.00	5.59	.05*			
Trail making (TMT-A)	Pre-test	Mid test	14.03	.837	.05*	58.33±3.78	425.03	.05*
		Post-test	26.29	1.19	.05*			
	Mid test	Pre-test	-14.03	.837	.05*	44.31±1.25		
		Post-test	12.27	.57	.05*			
	Post-test	Pre-test	-26.29	1.19	.05*	32.04±1.64		
		Mid test	-12.27	.569	.00*			
Trail making (TMT-B)	Pre-test	Mid test	126.75	14.62	.05*	539.17±56.12	142.97	.05*
		Post-test	231.29	17.48	.05*			
	Mid test	Pre-test	-126.75	14.62	.05*	412.42±6.36		
		Post-test	104.54	6.61	.05*			

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Dependent variables	Test		Bonferroni			M±SD	F	p
			Mean Difference	Std. Error	p			
	Post-test	Pre-test	-231.29	17.48	.05*	307.88±22.80		
		Mid test	-104.54	6.61	.05*			
Flanker Test Consistency	Pre-test	Mid test	-2.33	.23	.05*	2.92±0.79	156.83	.05*
		Post-test	-8.33	.58	.05*			
	Mid test	Pre-test	2.33	.23	.05*	5.25±0.75		
		Post-test	-6.00	.56	.05*			
	Post-test	Pre-test	8.33	.58	.05*	11.25±2.05		
		Mid test	6.00	.56	.05*			
Graphic design ability test	Pre-test	Mid test	-1.92	0.31	.05*	16.33±0.65	101.35	.05*
		Post-test	-5.08	0.36	.05*			
	Mid test	Pre-test	1.92	0.31	.05*	19.08±0.79		
		Post-test	-3.17	0.41	.05*			
	Post-test	Pre-test	5.08	0.36	.05*	22.25±1.36		
		Mid test	3.17	0.41	.05*			
Flanker test inconsistency	Pre-test	Mid test	-3.58	.19	.05*	16.33±0.65	1109.95	.05*
		Post-test	-7.67	.19	.05*			
	Mid test	Pre-test	3.58	.19	.05*	19.92±0.29		
		Post-test	-4.08	.08	.05*			
	Post-test	Pre-test	7.67	.19	.05*	24.00±0.00		
		Mid test	4.08	.08	.05*			

*P<.05

Table 9 found that all of the variables had pairwise significant differences (*P<.05).

Discussion

Summary of results: (1) In comparing the experimental and control groups, all variables related to badminton skills showed significant differences (*p<.05). (2) When comparing experimental and control groups, the cognitive ability test showed a significant difference (*p<.05); however, the mental rotation test did not. (3) There were significant differences (*P<.05) in badminton skills and cognitive ability across experimental groups at the pretest, mid-test, and post-test.

The influence of cognitive training on badminton skills, as observed in the experimental group outperforming the control group, can be attributed to the enhancement of cognitive functions such as focus, awareness, perception, reaction, anticipation, decision-making, and responsiveness. Cognitive training programs, like those described in the studies, aim to improve these mental skills, which are crucial for athletic performance. For instance, psychological skills training and mindfulness training have been shown to enhance attention control and emotional regulation, which are vital for maintaining focus and awareness during sports activities (Röthlin et al., 2020). Interventions to improve attentional focus in sports, like those used for football players, have shown significant enhancements in attentional control, indicating that these cognitive improvements can also benefit other sports, including badminton (Chan et al., 2020). Furthermore, the development of executive functions, which include decision-making and reaction time, has been linked to better sports performance, as seen in athletes with higher experience levels (Donka & Balogh, 2022). The Cognitive Fitness Framework (CF2) also supports the notion that cognitive fitness, which encompasses these skills, can be improved through deliberate practice, thereby enhancing readiness and performance in competitive settings (Aidman et al., 2022). Although the study on badminton athletes

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primarily focused on physical training methods, the integration of cognitive training could complement these methods by improving the mental aspects of performance, such as anticipation and decision-making, which were crucial for executing badminton techniques effectively (Azeez et al, 2023). Thus, cognitive training focusing on these areas likely contributed to the superior performance of the experimental group in badminton skills.

The improvement in badminton skills of the experimental group after training can be attributed to several factors, including the training program, exercise drills, intensity, volume of training, and recovery time. The multi-ball training program, as studied by Li Cheng and Prakit Hongsaenyatham, significantly enhanced the fundamental badminton skills such as high clear shot, drop shot, smash, and serve skills in young male students over 8 weeks, indicating the effectiveness of structured training programs in skill development (Li & Hongsaenyatham, 2023). Additionally, plyometric training has been shown to improve agility, speed, and explosive power in badminton players, as demonstrated in studies by Ankita Sharma et al. and K. Rangaraj and N. Ganapathy, which highlight the importance of dynamic exercises like hopping and jumping in enhancing athletic performance (Chandra et al., 2023; Rangaraj & Ganapathy, 2024). Electromyostimulation, another training modality, also contributed to improvements in jumping ability, although it was less effective than plyometrics in other areas (Panda et al., 2022). Furthermore, a 4-week badminton training program improved biometric parameters such as flexibility, reaction, and vertical jump, underscoring the role of specific training in enhancing physical attributes crucial for badminton (Yilmaz, 2022). While these studies focus on physical training, none explicitly address cognitive training, suggesting that the observed improvements were primarily due to physical conditioning rather than cognitive interventions. Overall, the combination of targeted physical training programs and appropriate recovery times appears to be key in enhancing badminton skills.

Conclusion

The cognitive training that includes awareness, perception, reaction, anticipation, decision-making, and responsiveness with an 8-week duration training and 3 days/week can improve badminton skills such as pace, serve, drop shot, smash, drive, and clear for secondary school students.

Recommendation

Suggestions in this research: From the research results, it was found that cognitive training combined with skill training resulted in increased skills. Therefore, in training athletes, cognitive training should be incorporated into training at all levels, whether basic, intermediate, or advanced.

Suggestions for next research: The cognitive training models that develop such things as focus, awareness, perception, reaction, anticipation, decision-making, and responsiveness should be developed for training athletes.

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