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Cognitive Enhancement Through Two-Handed Sword Training: A Single-Group Pre-Post Pre-Experimental Study in Healthy Thai Collegiate Sword Athletes

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Abstract:

Objective: This pre-experimental study examined the effects of an eight-week structured two-handed sword training program on cognitive function—specifically, processing speed, executive functions, and spatial ability—in healthy Thai collegiate sword athletes.

Material and Methods: Thirty-four healthy university students (25 males, 9 females) were selected via systematic random sampling. Participants completed an eight-week two-handed sword training program, three sessions per week. Perceived exertion and heart rate were recorded after each session. Cognitive function was assessed at baseline, week 4, and week 8 using a computerized battery, including Simple and Choice Reaction Time Tests, Trail Making Test (A and B), Flanker Test, Design Fluency Test, Mental Rotation Test, and Spatial Visualization Test. Data were analyzed using descriptive statistics and one-way repeated measures ANOVA or the Friedman test, with significance set at p-value<0.05.

Results: Significant improvements were observed in choice reaction time (effect size 1.27, CI=–1.26 to –0.58, p-value<0.001), attention (effect size 0.77, CI=–1.08 to –0.43, p-value=0.03), working memory (effect size 0.25, CI=–1.34 to –1.33, p-value<0.001), cognitive flexibility (effect size 1.05, CI=8.18 to 21.62, p-value<0.001), and spatial ability (effect size 0.56, CI=1.19 to 1.42, p-value<0.001). No significant changes were found in simple reaction time, cognitive inhibition, or selective attention.

Conclusion: The eight-week two-handed sword training program significantly enhanced cognitive performance, particularly in complex processing speed, executive functions, and spatial ability, indicating its potential as an effective cognitive enhancement intervention for young athletes.

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Introduction

In recent years, there has been growing recognition of the strong connection between physical activity and cognitive health. Regular physical exercise has been shown to promote neuroplasticity, increase cerebral blood flow, and stimulate the release of neurotrophic factors, such as brain-derived neurotrophic factor (BDNF), all of which contribute to improved brain structure and function[1]. Numerous studies demonstrate that consistent engagement in physical activity not only enhances physical fitness but also positively influences cognitive domains such as attention, memory, executive function, and processing speed[2]. These benefits are particularly critical for college students, who are frequently exposed to academic stress, irregular sleep patterns, and sedentary behaviors—factors associated with diminished mental performance and emotional well-being[3]. In particular, cognitive functions such as working memory, inhibitory control, and mental flexibility—key components of academic success—have been shown to be sensitive to both acute and chronic physical activity[4]. Engaging in structured and cognitively demanding physical activities during the university years may therefore serve as a preventive and developmental strategy to enhance cognitive resilience, academic performance, and long-term brain health. These findings underscore the importance of identifying novel, engaging, and sustainable forms of physical activity that support both physical and cognitive development in young adult populations.

Among the various forms of physical activity, the martial arts are notable for integrating physical, cognitive, and psychological components. Unlike repetitive or endurance-based exercises, martial arts involve complex motor sequences, strategic decision-making, and attentional control, stimulating cognitive processes such as response inhibition, task switching, working memory, and visuospatial awareness[5]. Two-handed sword training, found in disciplines like the European longsword and Japanese kendo, requires bilateral coordination, timing, mental focus, and structured practice, potentially engaging both brain hemispheres and supporting neurocognitive development[6]. Despite these cognitive demands, few studies have examined the effects of sword-based training on healthy young adults, with most research focusing on older or clinical populations[7-8]. Evidence shows that cognitively engaging physical activities—such as dual-task exercises, coordination drills, and skill-based movements like dance or martial arts—can enhance executive functions[9], attention control[10], and neural efficiency[11]. Activities requiring continuous adaptation, decision-making, and bilateral coordination appear especially effective in promoting neuroplasticity[12]. However, weapon-based martial training, including two-handed swordsmanship, remains understudied in healthy college populations. Investigating such interventions could provide valuable insights for physical education, mental health promotion, and skill-based athletic training among youth and young adults[13].

A growing body of evidence supports the idea that movement-based training programs—including aerobic exercise, balance training, coordination drills, and dual-task exercises—can significantly improve cognitive performance. These programs are known to stimulate executive functions such as working memory, inhibition, cognitive flexibility, and attention control, particularly when the activities are cognitively engaging[10]. For instance, dual-task training, which requires individuals to simultaneously perform motor and cognitive tasks, has been found to enhance neural efficiency and prefrontal cortex activation in young adults, suggesting a direct link between complex physical movement and cognitive processing[11]. Importantly, programs that involve novel, skill-based movements—such as dance, martial arts, or object manipulation—tend to produce stronger cognitive gains than simple aerobic exercise alone[12]. These cognitively enriched physical activities are especially beneficial when they require continuous adaptation, decision-making, and bilateral coordination, as they engage broader neural circuits and may promote long-term neuroplasticity[13]. However, despite this compelling evidence, there remains a notable gap in the literature concerning weapon-based or martial-style training, such as two-handed swordsmanship. Existing studies primarily focus on older adults, clinical populations, or general martial arts practice, often overlooking healthy young adult groups—particularly college students, who may benefit significantly from structured and stimulating physical programs[9]. Given the increasing interest in combining physical activity with cognitive training to support academic and neurological outcomes, investigating sword-based training interventions may open new pathways for physical education, mental health promotion, and skill-based athletic training among youth and young adults.

Despite the well-documented benefits of physical activity on cognitive function, there remains a need to identify engaging, accessible, and cognitively stimulating exercise modalities for young adults—particularly college students, who often face barriers such as time constraints, academic pressure, and lack of motivation. Two-handed sword training is uniquely relevant in this context because it integrates physical exertion, bilateral coordination, complex motor sequences, and attentional control within a structured and immersive environment. These features create a form of "enriched exercise" that simultaneously challenges both the body and mind, offering cognitive benefits beyond traditional aerobic routines. Moreover, its cultural and historical significance, combined with skill-based engagement, may enhance motivation and adherence among young adults. Investigating this modality in cognitively healthy populations addresses a gap in the literature, as most research has focused on older adults or clinical groups, thereby highlighting the potential of two-handed sword training not only to improve cognitive performance but also to serve as a model for designing holistic, skill-based exercise programs in educational and sports settings.

Therefore, the objective of this study was to investigate the effects of an eight-week structured two-handed sword training program on cognitive function—specifically, processing speed, executive functions, and spatial ability—in healthy Thai collegiate sword athletes. It is hypothesized that participation in the training program will result in significant improvements in cognitive domains, including processing speed, selective attention, and executive functions, when compared to pre-training baseline measurements.

Material and Methods

Before implementation of the study, it received approval from the Institutional Review Board of Thailand National Sports University (No. 042/2565) and adhered to the principles outlined in the Declaration of Helsinki.

Participants

The population for this research consisted of 120 first-year students from the Physical Education program at the National Sports University, Udon Thani Campus. Only first-year students were included to ensure a relatively homogeneous sample in terms of academic experience, age, and exposure to the university environment, which helps control for potential confounding variables. We acknowledge that this choice limits the generalizability of the findings to students in other years or age groups. Future studies should consider including students from multiple years to enhance the applicability of the results across a broader population. Participants included those who had no prior experience with two-handed sword training or krabi–krabong, could read and understand Thai instructions, and provided informed consent (with parental consent for minors), while those who attended less than 80% of training sessions, had injuries or pain preventing participation, or were unable or unwilling to continue were excluded. The sample size was calculated using G*Power 3.1.9.7, with an effect size of 0.50, α=0.050, and a power of 80.0%, resulting in a sample size of 27 participants. To prevent dropout, the researcher increased the sample size by 30 percent, resulting in a new sample size of 34 participants, selected through simple random sampling from this formula.

$$K = \frac{120}{34} = 3$$

Therefore, athletes with numbers 1, 4 (1+3), 7 (4+3), 10 (7+3), and 13 (10+3) were sampled and drawn randomly until the required number was reached.

Intervention

Initially, participants were familiarized with the two-handed sword training program before beginning the training to ensure accuracy. They were introduced to the training equipment, practiced basic movements, and received detailed instructions on standardizing techniques and minimizing errors during the program. Cognitive processing speed was assessed at three points: before training, after the 4th week, and after the 8th week. The training regimen included a 10-minute warm-up, 40 40-minute two-handed sword training program, and a 10-minute cool-down, conducted three times a week (Monday, Wednesday, Friday) over a total duration of 8 weeks. During the two-handed sword training program, the training intensity was assessed using the rating of perceived exertion (RPE) scale, which ranges from six to 20. On this scale, a level of six indicates no exertion, while a level of 20 indicates maximum exertion, according to the standard Borg RPE scale. The Rating of Perceived Exertion (RPE) was monitored throughout the training program. During weeks 1 to 2, the RPE was maintained between 9 and 11, measured immediately after each session. From weeks 3 to 8, the RPE was increased and maintained between 12 and 16, with assessments conducted at the 15th minute of exercise and immediately following each session. The overall mean perceived exertion across the intervention period was 12.91 (S.D.=0.14).

Additionally, heart rate (HR) was continuously monitored to assess exercise intensity throughout the training program. During the warm-up and cool-down phases, HR was maintained at a very light intensity level, corresponding to 50.0–60.0% of the maximum heart rate. In weeks 1 and 2 of skill training, HR was maintained at a light intensity level (60.0–70.0% of maximum heart rate), while in weeks 3 to 8, it was increased to a moderate intensity level (70.0–80.0% of maximum heart rate). The participants' mean resting heart rate was 83.86 beats per minute (bpm; S.D.=5.76), and the mean heart rate during exercise was 145.93 bpm (S.D.=2.82). The training program emphasized the practice and mastery of six specific offensive and defensive sword techniques, which were as follows (Table 1):

Strike 1: Neck-Neck (striking at the opponent's neck, left-right).

Strike 2: Neck-Neck-Legs-Legs (striking at the opponent's neck and legs, left-right).

Strike 3: Neck-Neck-Legs-Cross Legs or Raised Leg (striking at the opponent's neck and legs, left-right, with the final leg strike involving a raised leg and defensive strike).

Strike 4: Neck-Neck-Waist-Waist (striking at the opponent's neck and waist, left-right).

Strike 5: Neck-Neck-Waist-Waist-Head (striking at the opponent's neck, waist, and head).

Strike 6: Neck-Neck-Waist-Waist-Head-Thrust (striking at the opponent's neck, waist, head, and thrusting at the opponent).

Table 1 The two-handed sword training program

Week	Day	The two-handed sword training program	Intensity
1	Mon	Strike 1	- HR 60-70% of HR_{max} - RPE (9-11)
	Wed and Fri	Strike 1+Strike 2	
2	Mon	Strike 1+Strike 2+Strike 3	
	Wed and Fri	Strike 1/Strike 2+Strike 3+Strike 4	
3	Mon	Strike 1+Strike 2	
	Wed and Fri	Strike 3+Strike 4	
4	Mon	Strike 1+Strike 2+Strike 3	
	Wed	Strike 4+Strike 5+Strike 6	
	Fri	Strike 1+Strike 2+Strike 3+Strike 4+Strike 5+Strike 6	- HR 70-80% of HR_{max} - RPE (12-16)
5	Mon	Strike 1+Strike 3+Strike 5	
	Wed	Strike 2+Strike 4+Strike 6	
	Fri	Strike 1+Strike 2+Strike 5	
6	Mon	Strike 1 (2 times)+Strike 2+Strike 5	
	Wed and Fri	Strike 1+Strike 2+ Strike 4+Strike 5	
7	Mon, Wed, and Fri	Strike 1+Strike 2+Strike 3+Strike 4+Strike 5+Strike 6	
8	Mon, Wed, and Fri	Strike 1+Strike 2+Strike 3+Strike 4+Strike 5+Strike 6	

During the experiment, the researcher assessed the participants' perceived exertion levels and measured their heart rates before and after each training session. The training program was validated by three experts, who evaluated the congruence of the program's objectives using the Index of Item Objective Congruence (IOC), resulting in an average congruence score of 1.00.

Outcome measurement

Cognitive assessment tools

To evaluate the various aspects of cognitive function, a battery of computerized tests was administered, including the Choice Reaction Time Test, Trail Making Test, Flanker Test, Design Fluency Test, and Mental Rotation Test. The procedures and scoring methods for each are detailed below.

1. Cognitive processing speed was tested using the Simple and the Choice Reaction Time Test, as described below:

1.1 The simple reaction time test (SRT) was employed to evaluate cognitive processing speed. The test's reliability was assessed using intra-rater test-retest reliability. Pearson's correlation coefficient (r) was used to calculate this reliability, resulting in a coefficient of 0.998. The testing procedure is as follows: Participants must focus on the computer screen, and whenever a target object, a red circle, appears in the center of the screen, they should quickly press the "/" key on the keyboard with their index finger. The target object (stimulus) appears a total of 20 times. The results used for analysis include the average response time of correct responses (milliseconds).

1.2 The choice reaction time test (CRT) was used to assess processing speed, a fundamental cognitive ability. Pearson's correlation coefficient (r) was used to calculate this reliability, resulting in a coefficient of 0.773. Participants were required to fix their gaze on a computer screen and respond to visual stimuli under the following randomized conditions:

- When a red circle appeared at the center of the screen, participants pressed the "Z" key using the left index finger.

- When a blue circle appeared, they pressed the "/" key using the right index finger.

- When a yellow circle appeared, participants were instructed not to respond.

The test comprised 60 trials, with each stimulus type appearing 20 times. Performance was evaluated using the average response time of correct responses (milliseconds).

2. Attention and working memory were tested using the Trail Making Test A and B, as described below:

The Trail Making Test (TMT) assessed attention, executive function, cognitive flexibility, and working memory. Pearson's correlation coefficient (r) was used to calculate this reliability, resulting in a coefficient of 0.880. It consisted of two parts administered via computer:

- Part A: Participants clicked on numbers from 1 to 25 in ascending order as quickly and accurately as possible.

- Part B: Participants alternated between numbers and letters in sequence (e.g., 1 → A → 2 → B … 13 → L).

Scoring included the completion time, number of errors, time difference between Part B and Part A (B – A), and the B/A time ratio.

3. Cognitive inhibition and selective attention were tested using the Flanker Test (FKT), as described below:

The Flanker Test was designed to measure inhibitory control and selective attention, components of executive function. Pearson's correlation coefficient (r) was used to calculate this reliability, resulting in a coefficient of 0.867. The test included:

- Congruent trials: The central arrow pointed in the same direction as the surrounding arrows (e.g., <<<<<, >>>>>).

- Incongruent trials: The central arrow pointed in the opposite direction to the flankers (e.g., <<><<, >><>>).

Participants responded to the direction of the central arrow by pressing:

- "Z" (left index finger) if the arrow pointed left.

- "/" (right index finger) if the arrow pointed right.

The test comprised 40 trials (20 congruent, 20 incongruent). Outcome measures included average response time for correct trials (milliseconds).

4. Cognitive flexibility was tested using the Design Fluency Test (DFT), as described below:

The Design Fluency Test (DFT) assessed cognitive flexibility, a component of executive function. It required participants to generate as many unique visual designs as possible in 1 minute using four connected straight lines per design without repetition. Pearson's correlation coefficient (r) was used to calculate this reliability, resulting in a coefficient of 0.934. The test included three subtests:

- Filled dots: connect black dots.

- Empty dots: connect white dots.

- Switching dots: alternate between black and white dots.

Scoring was based on the number of correct, non-repetitive designs produced in each subtest and the combined total across all three.

5. Cognitive spatial ability was tested using the Mental Rotation Test (MRT) and Spatial Visualization Test (SVT), as described below:

5.1 The mental rotation test (MRT) assessed mental rotation ability, a key component of spatial cognition. Pearson's correlation coefficient (r) was used to calculate this reliability, resulting in a coefficient of 0.846. It consisted of two parts, each with 12 items. For each item, a target figure appeared on the left side of the screen, with four options on the right. Participants selected the two figures that matched the target, though rotated in orientation.

Each part had a 3-minute time limit, with a 2-minute break between sections. A correct response required both matching figures to be identified. Total scores ranged from 0 to 24 points.

5.2. Spatial visualization test (SVT) was employed to assess participants' ability to mentally manipulate and comprehend spatial relationships, an important facet of spatial ability. Pearson's correlation coefficient (r) was used to calculate this reliability, resulting in a coefficient of 0.932. The test involved presenting participants with a series of two- or three-dimensional figures, which they were required to analyze and manipulate mentally in order to identify the correct spatial transformations or correspondences.

Participants were given a set amount of time to complete a predetermined number of items, each requiring the identification of the correct spatial orientation or configuration among several options. Scoring was based on the total number of correct responses, reflecting the participant's spatial visualization proficiency.

Statistical analysis

Statistical analysis was performed using STATA version 13 (Texas, USA, 2007). The Shapiro-Wilk test was used to assess the normality of the data distribution. Descriptive statistics, including percentages, means, and standard deviations (S.D.), were calculated to summarize participant characteristics such as gender, age, heart rate, and perceived exertion. Inferential statistics were conducted using one-way repeated measures analysis of variance (ANOVA) to examine changes in cognitive function before training, after four weeks, and after eight weeks of training. When the assumption of normality was violated, the non-parametric Friedman test was applied as an alternative. A significance level of 0.05 was used for all statistical tests.

Results

The Shapiro-Wilk tests were conducted to assess the distribution of the cognitive test data. The results indicated that only the Design Fluency Test (DFT)was normally distributed (p-value=0.53). In contrast, the data for simple reaction time, choice reaction time, Trail Making, Flanker, mental rotation, and spatial ability were not normally distributed (p-value=0.00, 0.00, 0.00, 0.00, 0.04, and 0.00, respectively).

Cognitive processing speed

The effects of an eight-week structured two-handed sword training program on cognitive function—specifically, processing speed—were evaluated using simple and choice reaction time tests. For the simple reaction time test, the average reaction time decreased from 366.90 milliseconds at baseline to 301.50 milliseconds at week four and 301.20 milliseconds at week eight; however, these changes were not statistically significant, indicating no meaningful improvement in simple reaction time (p-value=0.11). In contrast, the choice reaction time test showed a reduction from 441.47 milliseconds at baseline to 433.63 milliseconds at week four and 410.83 milliseconds at week eight, with a statistically significant difference observed between the pre-test, 4^{th} week and the 8^{th} week, with a standardized effect size of 1.27 (95% CI=-1.26-0.58, p-value=0.00), suggesting that the training program significantly enhanced processing speed in tasks requiring complex decision-making (Figure 1).

Attention and working memory

Attention and working memory were evaluated using the Trail Making Test Parts A and B. The results from the Trail Making Test Part A, which assesses attentional performance, showed a progressive decrease in completion time from 36.71 milliseconds at pre-test to 34.78 milliseconds at the 4^{th} week, and 32.24 milliseconds at the 8^{th} week, which were statistically significant (p-value=0.00). For the Trail Making Test Part B, which measures working memory and cognitive flexibility, participants demonstrated a significant reduction in completion time from 81.70

milliseconds at pre-test to 68.55 milliseconds at the 4th week, and 58.18 milliseconds at the 8th week, which were highly significant, with a standardized effect size of 0.77 (95% CI=–1.08 to –0.43, p-value=0.03), suggesting that the eight-week structured two-handed sword training program had a substantial positive impact on working memory and executive function (Figure 2).

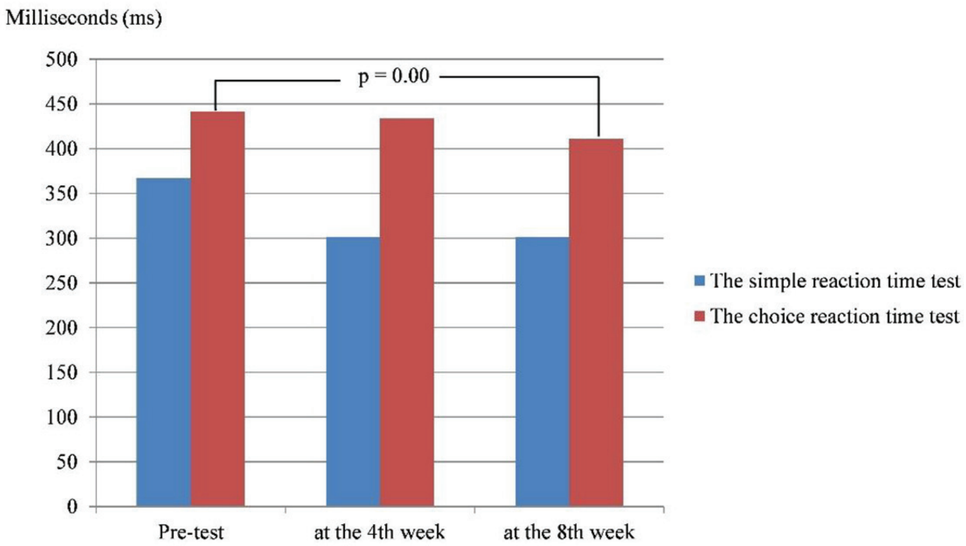

Figure 1 Cognitive processing speed

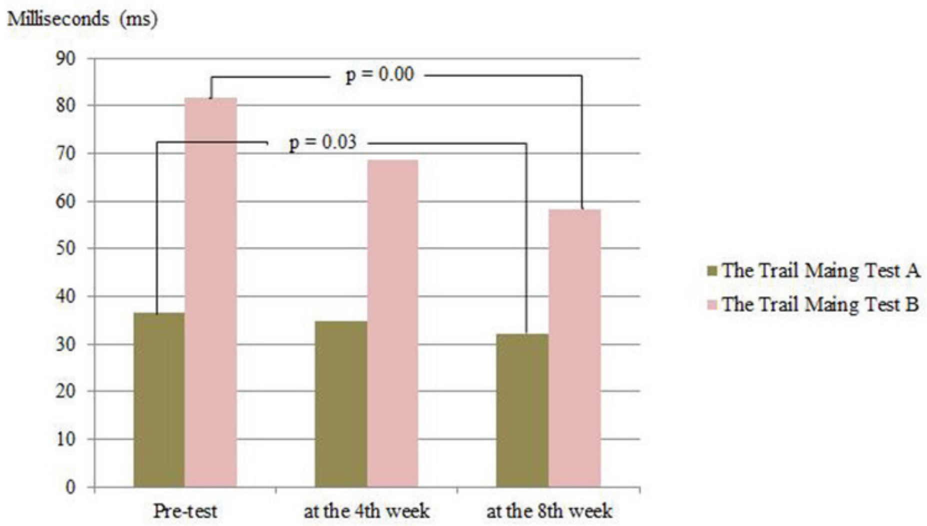

Figure 2 Attention and working memory

Cognitive inhibition and selective attention

Cognitive inhibition and selective attention were assessed using the Flanker Test (FKT), which includes both congruent and incongruent trials. In the congruent trial, the average reaction time decreased slightly from 412.53 milliseconds at pre-test to 408.07 milliseconds at the 4th week, and further to 404.67 milliseconds at the 8th week. Similarly, in the incongruent trial, the average reaction time improved from 464.87 milliseconds at pre-test to 457.07 milliseconds at the 4th week, followed by a slight decrease to 422.27 milliseconds at the 8th week. While both trials showed slight fluctuations in reaction time over the eight-week period, no statistically significant changes were observed, indicating that the two-handed sword training program had minimal effect on cognitive inhibition and selective attention, as measured by the Flanker Test (Figure 3).

Cognitive flexibility

Cognitive flexibility was assessed using the Design Fluency Test. The results demonstrated a statistically significant improvement over the eight-week training period (p-value=0.00). Participants' average scores increased from 7.23 points at pre-test to 7.33 points at the 4th week, and further to 10.30 points at the 8th week. These findings indicate a consistent and significant enhancement in cognitive flexibility, as measured by design fluency performance throughout the intervention, with a standardized effect size of 0.25 (95% CI=–1.34 to –1.33, p-value=0.00) (Figure 4).

Cognitive spatial ability

Cognitive spatial ability was assessed using the Mental Rotation Test and the Spatial Visualization Test. The results indicated a significant improvement in both

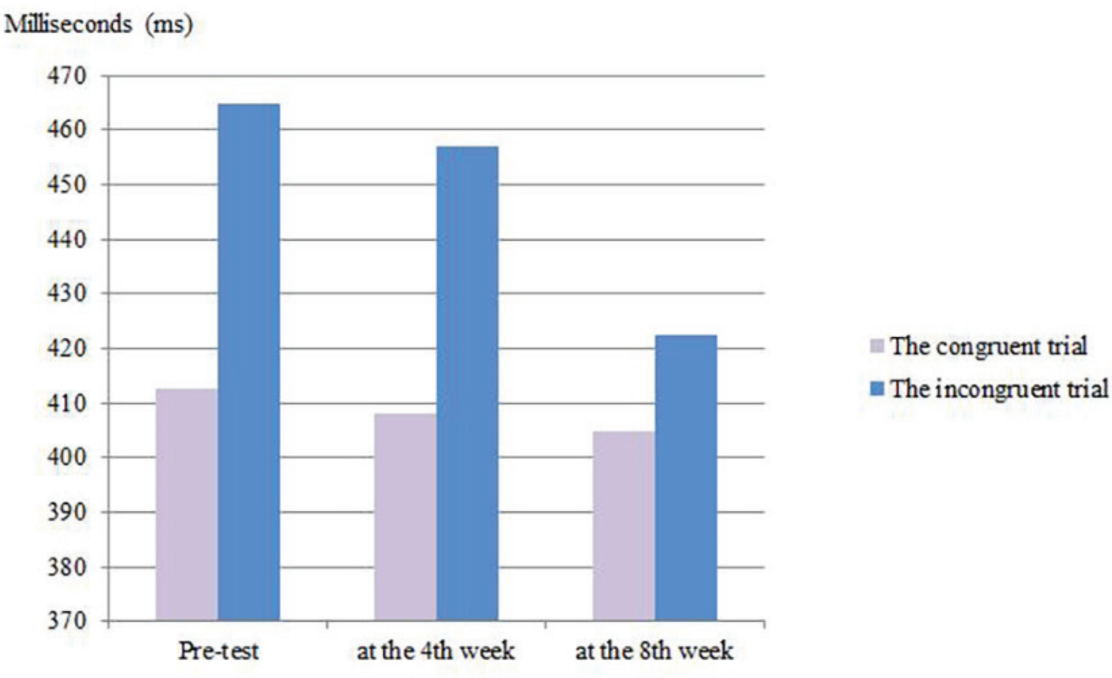

Figure 3 Cognitive inhibition and selective attention

measures over the eight-week training period. In the Mental Rotation Test, the average score increased from 5.13 points at pre-test to 7.03 points at the 4^{th} week, and further to 9.50 points at the 8^{th} week (p-value=0.00). Similarly, in the Spatial Visualization Test, participants' scores improved from 7.23 points at pre-test to 7.33 points at the 4^{th} week, and markedly to 10.30 points at the 8^{th} week. These findings suggest that the training program had a statistically significant and progressive effect on enhancing spatial cognitive functions, with a standardized effect size of 0.56 (95% CI=1.19 to 1.42, p-value=0.00) (Figure 5).

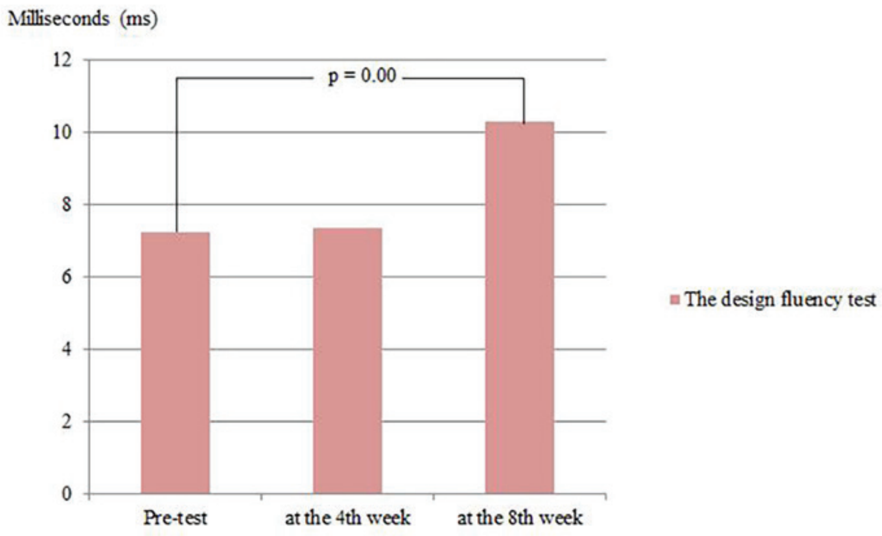

Figure 4 Cognitive flexibility

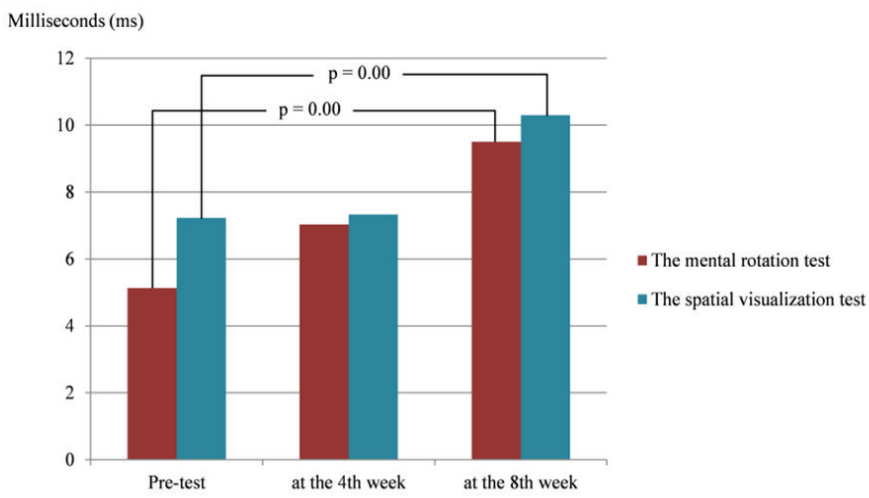

Figure 5 Cognitive spatial ability

Discussion

Cognitive processing speed

This study investigated the impact of an eight-week structured two-handed sword training program on cognitive processing speed in healthy Thai collegiate sword athletes. Processing speed was assessed using both simple and choice reaction time tasks. While simple reaction time showed no statistically significant changes, choice reaction time improved significantly by the eighth week, indicating enhanced cognitive efficiency in tasks involving complex decision-making. The lack of significant improvement in simple reaction time is consistent with previous findings suggesting that this measure primarily reflects basic sensorimotor functioning mediated by subcortical structures such as the spinal cord and brainstem[14]. These processes tend to be stable and less amenable to change, particularly in young, healthy adults whose baseline reaction times are already optimized[15]. Consequently, the minimal training-induced effect on simple reaction time is not unexpected. In contrast, the improvement in choice reaction time indicates enhanced higher-order cognitive processing, involving selective attention, working memory, and response inhibition—functions supported by the prefrontal cortex, supplementary motor area, and posterior parietal cortex[16]. The cognitively demanding, bilateral, and rhythmic nature of sword training likely stimulated these networks, promoting synaptic efficiency and cognitive-motor integration. These effects may be mediated by increased neuroplasticity, facilitated by enhanced cerebral blood flow and BDNF release[17]. Additionally, the dual-task demands of the training likely supported executive control and attentional resource allocation[18]. Overall, the findings support the cognitive benefits of complex motor-cognitive interventions, reinforcing evidence that such programs enhance executive function more effectively than simple aerobic activity[19]. Thus, cognitively enriched physical training may be a valuable strategy for improving cognitive efficiency in young adults. However, the absence of a control group limits the ability to draw definitive conclusions about causality. Alternative explanations, such as practice or test familiarity effects, variations in participant motivation, or placebo influences, cannot be ruled out. Therefore, while the observed improvements in choice reaction time are promising, they should be interpreted cautiously. Future studies incorporating a control group are warranted to more clearly isolate the specific effects of sword training on cognitive processing speed.

Attention and working memory

The present study examined the effects of an eight-week structured two-handed sword training program on attention and working memory in healthy university students, using the Trail Making Test (TMT) Parts A and B. The findings revealed significant improvements in both attentional control and working memory, as evidenced by a progressive and statistically significant reduction in task completion times over the eight-week period. The Trail Making Test Part A (TMT-A), which primarily measures visual attention, psychomotor speed, and processing efficiency, showed a significant decrease in completion time from baseline to week eight. This finding suggests that the training protocol effectively enhanced participants' attentional control, likely through the repeated engagement of the frontoparietal attention network, which includes the dorsolateral prefrontal cortex (DLPFC) and posterior parietal cortex[20]. These brain regions are responsible for sustained attention, shifting focus, and goal-directed attention, all of which are continually activated during complex motor tasks like the two-handed sword techniques that require rapid directional changes and target tracking. More notably, the results from the Trail Making Test Part B (TMT-B)—a task demanding working memory, cognitive flexibility, and task-switching—demonstrated a highly significant improvement across all time points, with the most pronounced change occurring between baseline and week eight. This supports the hypothesis that executive functions benefit more robustly from cognitively engaging physical activity compared to basic attention tasks[21]. The bilateral and coordinated nature of the sword training likely required ongoing updating of information, inhibition of prepotent responses, and set-shifting, all of which are central components of working memory and cognitive flexibility[22]. The neurobiological mechanisms underlying these improvements may include increased cerebral blood flow (CBF) and upregulation of neurotrophic factors, such as brain-derived neurotrophic factor (BDNF), which play critical roles in hippocampal plasticity, synaptogenesis, and prefrontal cortex efficiency[23]. Furthermore, motor-cognitive training that combines sequencing, rhythm, and bilateral coordination—as involved in this sword training program—has been shown to enhance functional connectivity between prefrontal and motor areas, promoting more efficient neural communication[24]. Recent research also emphasizes the role of dual-task training and open-skill activities—those requiring constant environmental adaptation—in promoting superior cognitive outcomes when compared to closed-skill or repetitive aerobic exercise[25]. Two-handed sword training qualifies as an open-skill, cognitively demanding activity, thus aligning with this growing body of evidence. The significant gains observed in TMT-B in this study suggest that such training modalities can be particularly effective in enhancing working memory capacity and executive processing, even in healthy, high-functioning young adults. In conclusion, the structured two-handed sword training program significantly improved both attentional control and working memory/executive function over an eight-week period. These findings support the integration of complex motor training programs into health and cognitive performance interventions, particularly those aimed at optimizing executive function through embodied, cognitively enriched physical activity. However, the absence of a control group limits the ability to draw definitive conclusions regarding causality. Alternative explanations, such as practice or test familiarity effects, variations in participant motivation, or placebo influences, cannot be ruled out. Therefore, while the observed improvements in TMT-A and TMT-B performance are promising, they should be interpreted with caution. Future studies incorporating a control group are warranted to more clearly isolate the specific effects of two-handed sword training on attentional control and working memory/executive function.

Cognitive inhibition and selective attention

This study demonstrated that an eight-week two-handed sword training program significantly enhanced cognitive spatial abilities, as measured by improvements in the Mental Rotation Test (MRT) and Spatial Visualization Test (SVT). The observed gains suggest enhanced function in neural networks involved in visuospatial working memory, motor planning, and spatial anticipation, particularly within the posterior parietal and premotor cortices[26]. The complex, bilateral, and rhythmically sequenced movements required in sword training likely strengthened sensorimotor coupling and spatiotemporal prediction, facilitating more efficient visual-motor integration and spatial information processing[27]. Neuroplastic adaptations, including increased white matter integrity and cortical thickness in frontoparietal regions, may underlie these improvements[23]. Consistent with evidence from other cognitively demanding physical activities, such as dance and martial arts, these findings support the efficacy of open-skill, coordination-based training in enhancing domain-general spatial cognition[18]. The results highlight the potential for integrating such motor-cognitive programs into athletic and educational contexts to foster spatial reasoning skills critical for STEM learning and complex motor tasks. However, the absence of a control group limits the ability to draw definitive conclusions regarding causality. Alternative explanations, such as practice or test familiarity effects, variations in participant motivation, or placebo influences, cannot be excluded. Therefore, while the observed improvements in MRT and SVT performance are promising, they should be interpreted with caution. Future studies incorporating a control group are warranted to more clearly isolate the specific effects of two-handed sword training on cognitive spatial abilities.

Cognitive flexibility

This study demonstrated that an eight-week two-handed sword training program significantly and progressively enhanced cognitive flexibility, as measured by the Design Fluency Test. Cognitive flexibility, a key executive function enabling adaptive behavior and novel problem solving, is supported by neural circuits involving the dorsolateral prefrontal cortex, anterior cingulate cortex, and orbitofrontal cortex[21]. The training's demands for continuous motor plan adaptation, bilateral coordination, and sequence variability likely engaged top-down cognitive control systems, enhancing task-switching and strategic response capabilities[24]. These findings align with prior research indicating that open-skill, coordinatively complex activities yield superior cognitive benefits over repetitive, closed-skill exercises[25]. Neurophysiologically, enhancements in cognitive flexibility may be mediated by increased brain-derived neurotrophic factor (BDNF), catecholamine regulation, and neurogenesis, promoting synaptic plasticity and frontoparietal activation[17]. The dose-dependent improvements observed suggest that sustained motor-cognitive training facilitates cumulative neural adaptations and behavioral gains[28]. Overall, these results highlight the efficacy of structured, cognitively engaging physical training for improving cognitive flexibility—beneficial for populations requiring rapid adaptation and complex decision-making. However, the absence of a control group limits the ability to draw definitive conclusions regarding causality. Alternative explanations, such as practice or test familiarity effects, variations in participant motivation, or placebo influences, cannot be excluded. Therefore, while the observed improvements in Design Fluency Test performance are encouraging, they should be interpreted with caution. Future studies incorporating a control group are warranted to more clearly isolate the specific effects of two-handed sword training on cognitive flexibility.

Conclusion

This study demonstrated that an eight-week two-handed sword training program significantly improved processing speed in complex tasks, attention, working memory, spatial ability, and cognitive flexibility. These findings highlight the potential of cognitively engaging, bilateral motor training to enhance multiple executive functions. However, no significant effects were observed for simple reaction time or cognitive inhibition, suggesting some cognitive domains may require different or longer interventions. Limitations include the lack of a control group and a homogeneous sample of healthy young adults, which may limit generalizability. Future randomized controlled studies with diverse populations are recommended to confirm and expand these results.

Limitation

This study has several limitations that should be considered when interpreting the findings. First, the absence of a control group prevents definitive attribution of observed improvements solely to the training intervention. Second, the relatively small sample size may reduce statistical power and the ability to detect subtle effects. Third, repeated testing introduces a high likelihood of learning or practice effects, which could have influenced performance gains. Finally, the sample consisted of young, physically active athletes, which limits the generalizability of the results to other populations. Future studies incorporating control groups, larger and more diverse samples, and methods to minimize practice effects are recommended to address these limitations.

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Conflict of interest

There are no potential conflicts of interest to declare.

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