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Enhancing Cognitive Processing Speed Through Two-Handed Sword Training in Thai Healthy University Students: A Pre-Experimental Study

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ABSTRACT

Introduction: Cognitive skills are one of the significant functions of being a healthy person. There are several approaches to improving human cognitive skills, including regular exercise. This pre-experimental research aimed to compare the two-handed sword training program on cognitive processing speed in healthy colleague students before training, during the 4th week, and after the 8th week of training.

Methods: Thirty-four healthy students (25 males and nine females) were chosen through systematic random sampling. The sample group performed a two-handed sword training program for eight weeks, three days a week. During the experiment, the researchers assessed the level of perceived exertion and took heart rate measurements after every training session. Data were collected by the simple reaction time test, which was employed to evaluate cognitive processing speed measured before, after four weeks, and after eight weeks by a computerized cognitive test battery. The descriptive statistics were analyzed by percentage, mean, and standard deviation. The inferential statistics were analyzed by one-way analysis of variance with repeated measures and the Friedman test. The significance level was set at 0.05.

Results: The comparison of cognitive processing speed before training and after the 8th week, specifically the response time in the choice reaction time test, showed a statistically significant decrease. The choice reaction time test also showed a statistically significant decrease in response time and accuracy rate when comparing the 4th and 8th weeks. The variation in cognitive processing speed after eight weeks of training showed a statistically significant difference in response time in the simple reaction time test. The choice reaction time test also showed a statistically significant difference in response time and accuracy rate.

Conclusion: The two-handed sword training improved cognitive processing speed, particularly in reaction time tests, but had no significant impact on other cognitive abilities, emphasizing the role of motor-based training in reaction-based decision-making.

Keywords: Two-handed sword training; Simple reaction time; Choice reaction time; Martial arts training; Cognitive function

Introduction

The two-handed sword, or "daab song mue," is a key component of Krabi Krabong, a traditional Thai martial art emphasizing weapon-based combat. Mastery of this weapon demands significant strength, agility, and precision, and is used in both offensive and defensive maneuvers. Krabi Krabong integrates a variety of other weapons and unarmed techniques, making it a comprehensive combat system. This martial art shares similarities with other Southeast Asian traditions, such as Pencak Silat and kbach kun boran [1]. The practice of Krabi Krabong, characterized by its continuous movement and exertion, serves as a form of aerobic exercise, offering benefits such as improved cardiovascular health, increased endurance, and reduced risk of chronic diseases.

The two-handed swordsmanship is a martial arts discipline that involves using a sword held with both hands to execute various combat techniques and movements. This practice combines physical skill with strategic thinking, focusing on improving strength, coordination, precision, and reaction time. The training often includes attacking, defending, and maneuvering techniques, emphasizing the development of physical abilities and cognitive skills such as decision-making and pattern recognition. The two-handed swordsmanship training program enhances cardiovascular health by improving efficiency and increasing VO2 max, leading to better heart function and circulation. These adaptations support both athletic performance and long-term health [2]. The program also significantly improves muscle strength and endurance, particularly in the forearms, shoulders, and core. It induces mild hypertrophy in the upper body, enhancing swordsmanship performance and overall muscular health.

Neuromuscular coordination and reaction time are markedly improved through the program. The complex techniques enhance brain-muscle efficiency, leading to more precise and fluid movements. Repeated practice fosters motor learning and reduces cognitive load, boosting overall skill proficiency and functional efficiency. Additionally, the training program enhances cognitive functions by improving processing speed and mental resilience. The demands on decision-making and pattern recognition boost brain performance, while the focus required increases mental resilience and stress management, benefiting both swordsmanship and daily life [2]. By integrating cardiovascular, muscular, neuromuscular, metabolic, and cognitive components, the two-handed sword training program leads to a well-rounded set of physiological adaptations. These adaptations improve physical performance in swordsmanship and contribute to overall health and cognitive function, making participants more efficient, resilient, and capable in physical and mental tasks [3].

Two-handed sword training is a martial art that uses a sword controlled with both hands, blending strength, technique, and precision. Originating from medieval European combat styles, it enhances physical fitness by engaging multiple muscle groups to improve strength, flexibility, and cardiovascular health. It also enhances motor skills, such as hand-eye coordination, balance, and body awareness. Additionally, it offers cognitive benefits by stimulating brain function and improving cognitive processing speed and reaction time. The training promotes stress relief and mental focus, fostering concentration, mindfulness, and emotional control, while also building foundational self-defense and martial arts skills that can be applied to modern techniques [2].

Cognitive processing speed significantly benefits athletic performance by enhancing decision-making, skill execution, reaction times, and adaptability. Athletes with improved processing speed can make quicker decisions, execute skills with greater precision, and respond more effectively to dynamic game situations. This improves their overall performance and competitiveness and provides a strategic advantage through better game awareness and reduced cognitive load. Ultimately, enhanced processing speed contributes to superior game intelligence and efficiency, making it a crucial factor in achieving athletic success. A study by Kadri et al. [4] examined the effect of taekwondo training on the processing speed of 40 adolescents, divided into a 20-person taekwondo training group and a 20-person control group. The study found that the taekwondo-trained group scored statistically significantly better on the Stroop color block test and the color-word interference test than the control group. These findings suggest that taekwondo training may positively affect cognitive function, particularly processing speed and cognitive flexibility. This may be due to the high degree of mental focus, concentration, physical coordination, and skill required in taekwondo training [5].

Physical exercise, including martial arts training, has increased blood flow and oxygen delivery to the brain, enhancing neural function and cognitive performance. Additionally, physical exercise has been shown to increase the production of growth factors such as brain-derived neurotrophic factor (BDNF), which can promote the growth and survival of neurons in the brain. Therefore, taekwondo training, as a form of physical exercise, may have a similar effect on the brain, resulting in increased activity in the frontal and lateral cerebral cortex, ultimately leading to improved processing speed and cognitive function. However, more research is needed to fully understand the neural mechanisms underlying the cognitive benefits of martial arts training [6]. Furthermore, some studies have found that physical activity can increase processing speed in children and adolescents [7]. These results could explain the long-term increase in hippocampal activity caused by hippocampal long-term potentiation (LTP) [8], the learning process of the nervous system, secretion of neocortical neurotrophin mRNA [9], diffuse density of cerebellar capillaries [10], and the chemical response catecholamine [11].

As with previous studies on exercise, martial arts are among the sports that can increase cognitive abilities, especially processing speed, and mental performance [12]. Additionally, some studies have shown that Tai Chi and traditional Chinese martial arts can reduce anxiety, daytime napping behavior, and expressions of inappropriate emotions. Other studies of taekwondo training have also found increases in brain activity, including processing speed. This is consistent with Cho, Kim, and Roh [13], who found that the group receiving regular taekwondo training demonstrated significantly faster performance on the Stroop color and word test than the control group. This aligns with the results of Cerrillo-Urbina et al. [14], who reviewed the effects of exercise on processing speed in both normal and ADHD children. Additionally, Cerrillo-Urbina et al. [14] reviewed 18 previous studies on the effects of aerobic exercise and yoga on children's emotional intelligence, finding that aerobic exercise had a moderately positive effect on emotional intelligence. A study by Fedewa and Ahn [15], which examined the effects of physical activity on cognitive function variables in children, found that aerobic exercise was more effective in increasing cognitive abilities than general physical education activities, including preliminary movement activities, with statistically significant results.

A few studies have specifically examined the effects of aerobic exercise, particularly traditional play activities, on athletes' and the general population's cognitive abilities and processing speed. Therefore, this pre-experimental study aimed to compare the effects of a two-handed sword training program on cognitive processing speed in healthy university students before training and after the fourth and eighth weeks. The hypothesis is that healthy colleague students will have better cognitive processing speed after 8 weeks compared to after 4 weeks and before the training.

Methods

Before implementation of the study, it had received approval from the Institutional Review Board of Thailand National Sports University (No. 042/2565) in Thailand and adhered to the principles outlined in the Declaration of Helsinki.The sample size was calculated by using the Rule of Thumb. From previous studies, there were three main factors related to the development

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. The sample size was calculated using G*Power 3.1.9.7, with an effect size of 0.50, $\alpha = 0.050$, 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 systematic 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, drawn randomly systematically 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 RPE levels were measured as follows: during weeks one to two, the RPE was set between nine and 11 (measured after each session), and during weeks three to eight, the RPE was set between 12 and 16 (measured at the 15th minute and after each session).

Additionally, heart rate (HR) was monitored to indicate the intensity of the exercise. During the warm-up and cool-down phases, the HR was maintained at a very light intensity level (50.0-60.0% of maximum heart rate). During weeks one and two of skill training, the HR was kept at a light intensity level (60.0-70.0% of maximum heart rate). For weeks three to eight, the HR was maintained at a moderate intensity level (70.0-80.0% of maximum heart rate). The training focused on practicing and mastering six specific strikes and defenses:

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).

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 (Fig 1).

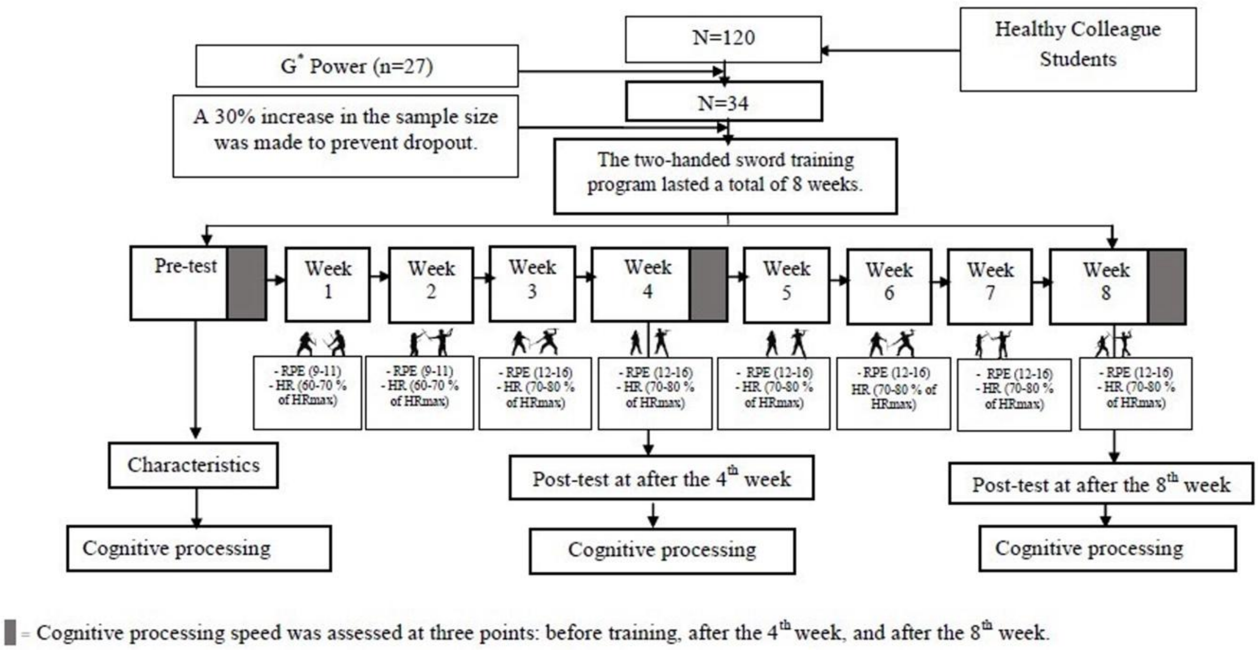

Figure 1 Research procedure

Outcome measurement

The Simple Reaction Time Test (SRT) was employed to evaluate cognitive processing speed [16]. 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 and the accuracy rate (percentage %) (Fig 2).

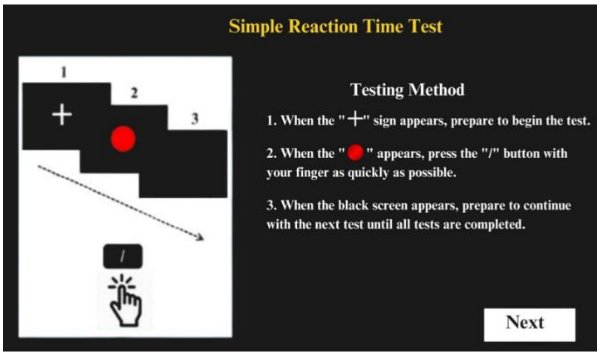

Figure 2 The simple reaction time test

Statistical analysis

Statistical analysis was conducted using STATA 13 (Texas, USA, 2007). The Shapiro-Wilk test assessed the normal distribution of values. Descriptive statistics, including percentages, means, and standard deviations (SD), were used to describe gender, age, heart rate, and perceived exertion. Inferential statistics involved one-way analysis of variance with repeated measures to analyze the variance in cognitive processing speed abilities before training, after four weeks of training, and after eight weeks. If the data did not meet the assumptions of normality, the Friedman test was used as an alternative. Statistical significance was set at the 0.05 level.

Results

The results of the assumption test revealed that the data for the cognitive processing speed test, both before training, after the 4th week, and after the 8th week (p = 0.38, 0.28, and 0.21, respectively), which is in accordance with the assumption on the use of parametric statistics.

Characteristics

The sample group consisted of 34 individuals, including 25 males (73.5%) and nine females (26.4%), with an average age of 19.2 years. The average resting heart rate was 83.8 beats per minute (bpm), while the average heart rate during exercise was 145.9 bpm. The rating of perceived exertion was 12.9 (Table 1).

Table 1 Descriptive statistics of heart rate and perceived exertion during training

Parameter	Mean or SD
Heart rate	
Resting	83.8 (5.7) Min-max (81.7-86.2)
Exercise	145.9 (2.8) Min-max (145.9-152.0)
Rating of perceived exertion	12.9 (0.1) Min-max (12.9-14.0)

The processing speed

The cognitive processing speed of the simple reaction time test showed the following results: the average response times were 366.9 ms (SD = 210.1), 301.50 ms (SD = 46.37), and 301.2 ms (SD = 39.0), respectively. The average accuracy rates were 99.0% (SD = 2.03), 98.1% (SD = 3.0), and 98.3% (SD = 4.97), respectively. For the choice reaction time test, the average response times were 441.4 ms (SD = 56.6), 433.6 ms (SD = 42.1), and 410.8 ms (SD = 33.1), respectively. The average accuracy rates were 88.6% (SD = 17.5), 98.1% (SD = 3.07), and 93.6% (SD = 11.5), respectively (Table 2).

Table 2 Cognitive processing speed before training, after the 4th week, and after the 8th week

Processing speed	Before training mean (SD)	After the 4th week mean (SD)	After the 8th week mean (SD)
Simple reaction time			
Response time (milliseconds)	366.9 (210.1)	301.5 (46.3)	301.2 (39.0)
Accuracy rate (%)	99.0 (2.0)	98.1 (3.0)	98.3 (4.9)
Choice reaction time test			
Response time (milliseconds)	441.4 (56.6)	433.6 (42.1)	410.8 (33.1)
Accuracy rate (%)	88.6 (17.5)	98.1 (3.0)	93.6 (11.5)

The comparison of cognitive processing speed before training, after the 4th week, and after the 8th week

The comparison of cognitive processing speed before training and after the 8th week, specifically the response time in the choice reaction time test, showed a statistically significant decrease (p-value< 0.001) (Table 4). The choice reaction time test also showed a statistically significant decrease in both response time and accuracy rate when comparing the 4th and 8th weeks (p-value<0.001 and p-value = 0.001, respectively) (Table 5). However, no statistically significant differences were observed in other cognitive abilities (Table 3).

Table 3 Comparison of cognitive processing speed before training and after the 4th week

Source of Variance	Intervention	Value	Dependent sample t-test $\bar{d}$	SD	SE	t	df	p-value
Processing speed								
Simple reaction time								
Response time (milliseconds)	Before	366.9	65.4	191.8	35.0	1.87	29	0.070
	4th week	301.5						
Accuracy rate (%)	Before	99.0	0.8	3.2	0.5	1.41	29	0.170
	4th week	98.1						
Choice reaction time test								
Response time (milliseconds)	Before	441.4	7.8	45.1	5.2	0.95	29	0.350
	4th week	433.6						
Accuracy rate (%)	Before	88.6	-1.9	15.4	2.8	0.68	29	0.500
	4th week	90.5						

Table 4 Comparison of cognitive processing speed before training and after the 8th week

Source of Variance	Intervention	Value	Dependent sample t-test					
			$\overline{d}$	SD	SE	t	df	p-value
Processing speed								
Simple reaction time								
Response time (milliseconds)	Before	366.9	65.7	205.6	37.5	1.75	29	0.910
	8th week	301.2						
Accuracy rate (%)	Before	99.0	0.6	5.6	1.0	0.64	29	0.560
	8th week	98.3						
Choice reaction time test								
Response time (milliseconds)	Before	441.4	30.6	54.0	9.8	3.10	29	0.001*
	8th week	410.8						
Accuracy rate (%)	Before	88.6	-4.9	14.2	2.6	1.91	29	0.070
	8th week	93.6						

Table 5 Comparison of cognitive processing speed after the 4th week, and after the 8th week

Source of Variance	Intervention	Value	Dependent sample t-test					
			$\overline{d}$	SD	SE	t	df	p-value
Processing speed								
Simple reaction time								
Response time (milliseconds)	4th week	301.50	0.3	34.2	6.2	0.05	29	0.960
	8th week	301.20						
Accuracy rate (%)	4th week	98.17	-0.1	5.6	1.0	-0.16	29	0.870
	8th week	98.33						
Choice reaction time test								
Response time (milliseconds)	4th week	433.63	22.8	32.0	5.8	3.90	29	0.001*
	8th week	410.83						
Accuracy rate (%)	4th week	90.53	-3.0	5.8	1.0	-2.87	29	0.010*
	8th week	93.60						

The variance in cognitive processing speed after the 8th week of training

The variation in cognitive processing speed after eight weeks of training showed a statistically significant difference in response time in the simple reaction time test (p-value = 0.040) (Table 6). The choice reaction time test also showed a statistically significant difference in both response time and accuracy rate (p-value <0.001 and p-value < 0.001, respectively) (Table 6).

Table 6 Variation in cognitive processing speed ability after 8 weeks of training (n = 30)

Source of Variation	SS	df	MS	F	P
Within group					
Simple reaction time test					
- Response time (milliseconds)					
Time	85937.4	2	21075.7	3.21	0.040*
Error	775930.6	58	42968.7		
- Accuracy rate (%)					
Time	11.6	2	13.4	0.47	0.440
Error	721.6	58	5.8		
Choice reaction time test					
- Response time (milliseconds)					
Time	15196.0	2	4086.9	7.61	<0.001*
Error	57913.9	58	7598.0		
- Accuracy rate (%)					
Time	376.8	2	422.2	2.39	<0.001*
Error	4577.8	58	188.4		

Discussion

The comparison of cognitive processing speed before and after 8 weeks of training showed a significant decrease in response time in the choice reaction time test. Additionally, significant improvements were observed in both response time and accuracy between the 4th and 8th weeks. The simple reaction time test also showed a significant difference in response time, while the choice reaction time test showed significant changes in both response time and accuracy. This improvement is likely due to several physiological adaptations that enhance neuromuscular efficiency and cognitive function. The mechanisms responsible for these enhancements can be categorized into neuroplasticity, neural transmission efficiency, structural brain adaptations, sensory-motor improvements, cardiovascular benefits, motor learning, and neuroendocrine regulation [17]. Solanki et al. [18] confirmed that sword training requires complex hand-eye coordination, rapid decision-making, and precise motor execution. These repeated cognitive and physical demands stimulate neuroplastic changes in the prefrontal cortex and motor cortex, enhancing processing speed and reaction time.

With consistent practice, neural pathways strengthen, leading to more efficient cognitive-motor integration and faster reaction times. Previous studies have supported the idea that high-intensity motor training increases synaptic efficiency by enhancing neurotransmitter activity, particularly dopamine and acetylcholine, which are essential for attention, movement control, and reaction time [19]. Faster synaptic transmission results in quicker neural responses, leading to a significant decrease in choice reaction time.

According to Adami et al. [20], motor skill training has been linked to improvements in white matter integrity in brain regions responsible for cognitive processing, such as the corpus callosum and corticospinal tract. These structural enhancements facilitate faster interregional communication, allowing for quicker and more accurate information processing during reaction-based tasks [21]. Sword training enhances sensory-motor processing, enabling individuals to respond more efficiently to external stimuli. The central nervous system (CNS) adapts by reducing neural delays in decision-making, which is reflected in faster reaction times in the choice reaction time test [22].

Regular physical training improves cardiovascular efficiency, resulting in better oxygen and glucose delivery to the brain. Increased cerebral blood flow (CBF) particularly benefits the frontal lobe, which plays a crucial role in decision-making and cognitive speed. These physiological changes help optimize cognitive processing and improve reaction time [23]. Repeated exposure to sword drills promotes automaticity in movement patterns, reducing cognitive load during response execution. As movements become more reflexive, the brain processes choices more efficiently, leading to faster and more accurate reactions [24]. Regular training helps regulate cortisol levels, reducing cognitive stress and enhancing focus and reaction time.

Additionally, the release of catecholamines (dopamine, norepinephrine) during training improves attentional control, arousal, and decision-making speed. These hormonal changes contribute to overall cognitive efficiency and reaction speed. While the two-handed sword training program significantly improved reaction time in the Choice Reaction Time Test, no statistically significant differences were observed in other cognitive abilities such as memory, executive function, or problem-solving. This outcome can be explained by two key factors: Cognitive improvements resulting from physical training are often task-specific. Since the training primarily emphasizes rapid decision-making and motor responses, it directly enhances reaction time.

However, cognitive abilities unrelated to reaction-based decision-making, such as working memory, abstract reasoning, or strategic planning, do not receive the same level of stimulation and, therefore, remain unchanged [25]. The neuroplastic changes induced by sword training predominantly affect sensorimotor and reaction-based pathways, particularly in the motor cortex and prefrontal cortex. In contrast, higher-order cognitive functions rely on different neural networks, such as the hippocampus (memory) or dorsolateral prefrontal cortex (executive function), which are not significantly activated by this type of training. Consequently, improvements are seen in reaction-based cognition, while more complex cognitive abilities remain unaffected [26].

Conclusion

The two-handed sword training program has shown promise as an effective cognitive training method for enhancing quick decision-making skills. This training improves cognitive processing speed through various physiological mechanisms, including neuroplasticity, enhanced neural transmission, brain structural improvements, sensory-motor efficiency, cardiovascular benefits, motor learning, and neuroendocrine regulation. These adaptations contribute to significant improvements in reaction time, particularly in the choice reaction time test, highlighting the cognitive benefits of high-intensity, skill-based motor training. However, the lack of statistically significant differences in other cognitive functions suggests that the cognitive benefits derived from physical training are domain-specific. While the two-handed sword training program effectively enhances reaction-based cognitive processing, it does not significantly affect higher-order cognitive functions, which likely require different forms of cognitive engagement and targeted training stimuli.

Future research should explore combining two-handed sword training with cognitive tasks or dual-task training to assess potential synergistic effects on executive functions, working memory, and problem-solving abilities. Longitudinal studies with larger, more diverse populations and neuroimaging tools could also provide deeper insights into the neural mechanisms underlying cognitive improvements. In addition, varying the training intensity, frequency, or integrating other motor-cognitive interventions may help broaden the cognitive benefits observed.

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Conflict of Interest

No Conflict of Interest

References

[1] Draeger DF, Smith R. Comprehensive Asian Fighting Arts. Kodansha USA; 1981.

[2] Pickford J. Two-hand sword and two-handed sword. Notes and Queries. 1887;7th Series, III (60):156.

[3] Lee T, Swinnen SP, Serrien D. Cognitive effort and motor learning. Quest. 1994;46(3):328–344. doi: 10.1080/00336297.1994.10484130.

[4] Kadri A, Slimani M, Bragazzi NL, Tod D, Azaiez F. Effect of taekwondo practice on cognitive function in adolescents with attention deficit hyperactivity disorder. International Journal of Environmental Research and Public Health. 2019;16(2):204. doi: 10.3390/ijerph16020204.

[5] Vazou S, Pesce C, Lakes K, Smiley-Oyen A. More than one road leads to Rome: A narrative review and meta-analysis of physical activity intervention effects on cognition in youth. International Journal of Sport and Exercise Psychology. 2019;17(2):153–178. doi: 10.1080/1612197X.2016.1223423.

[6] Nęcka E, Gruszka A, Hampshire A, Sarzyńska-Wawer J, Anicai AE, Orzechowski J, et al. The effects of working memory training on brain activity. Brain Sciences. 2021;11(2):155. doi: 10.3390/brainsci11020155. PMID: 33503877; PMCID: PMC7911688.

[7] Halperin JM, Marks DJ, Chacko A, Bedard AC, O'Neill S, Curchack-Lichtin J, et al. Training executive, attention, and motor skills (TEAMS): a preliminary randomized clinical trial of preschool youth with ADHD. Journal of Abnormal Child Psychology. 2020;48(3):375–389. doi: 10.1007/s10802-019-00610-w.

[8] Ávila-Gámiz F, Pérez-Cano AM, Pérez-Berlanga JM, Mullor-Vigo RM, Zambrana-Infantes EN, Santín LJ, et al. Sequential treadmill exercise and cognitive training synergistically increase adult hippocampal neurogenesis in mice. Physiology & Behavior. 2023;266:114184. doi: 10.1016/j.physbeh.2023.114184. Epub 2023 Apr 6. PMID: 37030425.

[9] Kaagman DGM, van Wegen EEH, Cignetti N, Rothermel E, Vanbellingen T, Hirsch MA. Effects and mechanisms of exercise on brain-derived neurotrophic factor (BDNF) levels and clinical outcomes in people with Parkinson's disease: a systematic review and meta-analysis. Brain Sciences. 2024;14(3):194. doi: 10.3390/brainsci14030194. PMID: 38539583; PMCID: PMC10968162.

[10] Kleim J, Vij K, Ballard DH, Greenough WT. Learning-dependent synaptic modifications in the cerebellar cortex of the adult rat persist for at least four weeks. The Journal of Neuroscience. 1997;17(2):717–21. doi: 10.1523/JNEUROSCI.17-02-00717.1997.

[11] Nemet D, Ben-Zaken S, Eliakim A. The effect of methylphenidate on the dopamine and growth hormone response to exercise in children with attention-deficit hyperactivity disorder. Growth Hormone and IGF

Research. 2024;76:101596. doi: 10.1016/j.ghir.2024.101596.
[12] Shapiro F. EMDR as an integrative psychotherapy approach: experts of diverse orientations explore the paradigm prism. American Psychological Association; 2002. p. 3–26. doi: 10.1037/10512-001.
[13] Cho SY, Kim YI, Roh HT. Effects of taekwondo intervention on cognitive function and academic self-efficacy in children. Journal of Physical Therapy Science. 2017;29(4):713–715. doi: 10.1589/jpts.29.713.
[14] Cerrillo-Urbina AJ, García-Hermoso A, Sánchez-López M, Pardo-Guijarro MJ, Santos Gómez JL, Martínez-Vizcaíno V. The effects of physical exercise in children with attention deficit hyperactivity disorder: a systematic review and meta-analysis of randomized control trials. Care, Health and Development. 2015;41(6):779–788. doi: 10.1111/cch.12255.
[15] Jaekel J. The role of physical activity and fitness for children's wellbeing and academic achievement. Pediatr Res. 2024;96:1550–1551. doi: 10.1038/s41390-024-02775-x.
[16] Yongtawee A, Pitaksethiarakun C, Noikhammuang T, Sukdee N. Sport intelligence: the role of cognitive abilities in sports success among Thai youth athletes. Bangkok: Department of Physical Education, Ministry of Tourism and Sports; 2020.
[17] Amini Vishteh RA, Mirzajani A, Jafarzadehpour E, Darvishpour S. Evaluation of simple visual reaction time to different colored light stimuli in visually normal students. Clinical Optometry (Auckland). 2019;11:167–171. doi: 10.2147/OPTO.S236328.
[18] Salkar P, Dave J, Deo M. Correlation between simple visual and auditory reaction time with falls efficacy in community dwelling older adults. International Journal of Creative Research Thoughts. 2023 Jun;11(6):1034-1039. doi: 10.5530/ijmedph.2.2.8.
[19] Prien A, Junge A, Brugger P, Straumann D, Feddermann-Demont N. Neurocognitive performance of 425 top-level football players: sport-specific norm values and implications. Archives of Clinical Neuropsychology. 2018;34(4):575–584. doi: 10.1093/arclin/acy056.
[20] Adami R, Pagano J, Colombo M, Platonova N, Recchia D, Chiaramonte R, et al. Reduction of movement in neurological diseases: effects on neural stem cell characteristics. Frontiers in Neuroscience. 2018;12:336. doi: 10.3389/fnins.2018.00336.
[21] Guure CB, Ibrahim NA, Adam MB, Said SM. Impact of physical activity on cognitive decline, dementia, and its subtypes: a meta-analysis of prospective studies. BioMed Research International. 2017;2017:9016924. doi: 10.1155/2017/9016924.
[22] Basso JC, Oberlin DJ, Satyal MK, O'Brien CE, Crosta C, Psaras Z, et al. Examining the effect of increased aerobic exercise in moderately fit adults on psychological state and cognitive function. Frontiers in Human Neuroscience. 2022;16:833149. doi: 10.3389/fnhum.2022.833149.
[23] Basso JC, Suzuki WA. The effects of acute exercise on mood, cognition, neurophysiology, and neurochemical pathways. Brain Plasticity. 2017;2(2):127–152. doi: 10.3233/BPL-160040.
[24] Kroneisen M, Erdfelder E, Groß RM, Janczyk M. Survival processing occupies the central bottleneck of cognitive processing: a psychological refractory period analysis. Psychonomic Bulletin & Review. 2024;31(1):274–282. doi: 10.3758/s13423-023-02340-z.
[25] Ohtani T, Matsuo K, Sutoh C, Oshima F, Hirano Y, Wakabayashi A, et al. Reduced brain activation in response to social cognition tasks in autism spectrum disorder with and without depression. Neuropsychiatric Disease and Treatment. 2021;17:3015–3024. doi: 10.2147/NDT.S327608.
[26] Gormley J, Fager SK. Preference and visual cognitive processing demands of alphabetic and QWERTY keyboards of individuals with and without brain injury. Assistive Technology. 2022;34(3):341–351. doi: 10.1080/10400435.2020.1826006.