



Designing a Complex Training Program to Enhance Specific Fitness and Kick Performance in Wushu Sanda Athletes

Yuan Xu, Wisute Tongdecharoen, and Prakrit Hongsaenyatham

Faculty of Sports Science and Technology, Bangkokthonburi University, Thailand

E-mail: 1401368355@qq.com, ORCID ID: <https://orcid.org/0009-0009-2117-4652>

E-mail: wisute.ton@bkkthon.ac.th, ORCID ID: <https://orcid.org/0009-0008-5233-7533>

E-mail: prakitsport@gmail.com, ORCID ID: <https://orcid.org/0009-0009-2196-0258>

Received 27/09/2025

Revised 08/10/2025

Accepted 30/10/2025

Abstract

Background and Aims: Wushu Sanda performance requires the integration of neuromuscular power and cognitive skill, yet traditional training often fails to bridge the gap between gym-based fitness and competitive application. This study designed and evaluated an integrated complex training program to simultaneously enhance specific fitness, kick performance, and cognitive abilities in youth Sanda athletes.

Methodology: Thirty male Wushu Sanda athletes (17.20 ± 0.75 years) were randomly assigned to an experimental group ($n=15$) that underwent an 8-week integrated complex training program or a control group ($n=15$) that continued conventional training. The program combined high-intensity resistance, plyometric, and cognitive-perceptual drills. Performance was assessed pre-, mid-, and post-intervention using validated tests for physical fitness (strength, power, RFD), kick performance (power, velocity), and cognitive function (reaction time, decision-making).

Results: The experimental group showed significantly greater improvements ($p < .05$) compared to the control group across all domains, including maximal strength (+10.5% vs. +2.1%), explosive power (+13.9% vs. +2.4%), kick power (+10.8% vs. +2.3%), and choice reaction time (−11.1% vs. −1.2%), with large effect sizes.

Conclusion: An integrated complex training approach is a highly effective methodology for concurrently developing the physical and cognitive attributes essential for Wushu Sanda. This evidence-based paradigm provides a superior alternative to conventional training for optimizing athlete performance.

Keywords: Complex Training; Wushu Sanda; Specific Fitness; Kick Performance

Introduction

A central challenge in modern high-performance combat sports is the effective transfer of physical capacities developed in training to functional, adaptive performance in competition. Athletes often exhibit a “performance paradox,” where high levels of gym-based strength and



power do not translate into timely and effective techniques under the pressure of a live opponent (Joyce & Lewindon, 2022). This issue is particularly pronounced in Wushu Sanda, a dynamic combat sport of immense cultural and competitive significance in China, which combines long-range kicking and striking with close-quarters grappling on a raised lei tai platform (Zubia et al., 2021). For youth athletes in specialized programs, such as those at Maling High School, optimizing training to bridge this gap is critical for national and international success. Among Sanda's techniques, kicking is paramount, serving not only as a primary scoring tool but also as a method for controlling distance and creating strategic advantages (Gavagan & Sayers, 2017).

Successful kicking is a complex, multifactorial skill that relies on the seamless integration of physical and cognitive qualities. The physical foundation requires a robust neuromuscular system capable of producing maximal strength, which is then converted into explosive power at a high rate of force development (RFD) (Loturco et al., 2019). However, these physical attributes are only effective if deployed within the fleeting milliseconds of a competitive opportunity. This necessitates advanced cognitive functions, including rapid perceptual processing of an opponent's movements, accurate anticipation, and swift tactical decision-making to initiate the correct motor response (Grgic et al., 2021). Compounding this challenge, accumulating fatigue during a match degrades not only muscular output but also executive functions, leading to slower reactions and poor choices (Hadlow et al., 2018; O'Brien et al., 2022).

Traditional training methodologies in Wushu Sanda often address these components in isolation; physical conditioning is separated from technical drills, which are separated from sparring. This compartmentalized approach is inconsistent with modern skill acquisition theories, such as the constraints-led approach, which emphasizes the interaction between the athlete, the task, and the environment (Renshaw et al., 2019). While Complex Training (CT), which pairs a heavy resistance exercise with a biomechanically similar plyometric drill, has emerged as a potent method for enhancing explosive power via Post-Activation Performance Enhancement (PAPE) (Seitz & Haff, 2016; Grgic et al., 2022), standard CT protocols often fail to incorporate the necessary cognitive-perceptual stressors that define competition. This omission limits the ecological validity of the training and its transfer to the chaotic, open-skill environment of a Sanda match (Farrow, 2019).

Therefore, a significant gap exists in the scientific literature concerning holistic training models that systematically integrate the neuromuscular and cognitive demands specific to Wushu Sanda. While the physical benefits of CT are established, its application remains underexplored in Sanda, and it has not been combined with sport-specific cognitive challenges to foster superior skill transfer. The purpose of this study was to design and evaluate an integrated complex training program that combines resistance, plyometric, and cognitive-perceptual training to





simultaneously improve specific fitness and kick performance in youth Wushu Sanda athletes. This research seeks to provide coaches and practitioners with an evidence-based, ecologically valid training paradigm to bridge the gap between training and competition, thereby advancing athlete development in high-performance combat sports.

Objectives

The main objective of this study was to design and evaluate the effects of a complex training program on specific fitness and kick performance for Wushu Sanda athletes. The specific objectives were:

1. To develop an integrated complex training program for Wushu Sanda athletes that combines strength, plyometric, and cognitive-perceptual components.
2. To study the effects of the developed program on the specific fitness, kick performance, and cognitive abilities of Wushu Sanda athletes.
3. To compare the changes in performance measures from before the intervention to after the intervention between the experimental group and the control group.
4. To analyze the progressive performance changes within the experimental group across pre-test, mid-test, and post-test assessments.

Literature Review

Contemporary sports science reveals that combat sport performance emerges from the dynamic integration of neuromuscular capacities and cognitive-perceptual abilities rather than their isolated development (Ciaccioni et al., 2024). Complex training, which strategically combines high-intensity resistance exercises with biomechanically similar plyometric movements, has demonstrated superior effectiveness in enhancing explosive strength through Post-Activation Performance Enhancement (PAPE) mechanisms (Dello Iacono et al., 2024). The neurophysiological adaptations underlying PAPE include heightened neural drive, myosin regulatory light chain phosphorylation, and optimized motor unit recruitment patterns, collectively contributing to enhanced rate of force development and explosive power output (Rauscher et al., 2024). Recent evidence from Krzysztofik et al. (2024) indicates that complex training protocols produce 8-15% improvements in reactive strength measures among combat sport athletes when implemented over 8-12 week periods. Similarly, Chen et al. (2023) demonstrated that integrating resistance and plyometric training within single sessions yielded superior transfer effects to sport-specific performance compared to traditional block periodization approaches in martial artists.

The transfer of physical qualities to technical execution in combat sports depends critically on the integration of decision-making, perceptual skills, and reaction speed under physiological





stress (Turner et al., 2023). Chaabene et al. (2023) reported that combining neuromuscular training with sport-specific cognitive tasks significantly improved striking performance in martial artists, suggesting that ecological validity is enhanced when cognitive-perceptual challenges are embedded within physical training protocols. This integrated approach aligns with the principle of transfer-appropriate processing, where training conditions sharing similar neurocognitive processing requirements with competitive performance demonstrate superior transfer effects (Ramirez-Campillo et al., 2023). Moran et al. (2024) further substantiated this framework, showing that complex training incorporating decision-making tasks improved agility and reactive strength performance in youth athletes by 12-18%, exceeding gains from purely physical training protocols.

Emerging evidence emphasizes the critical role of perceptual-cognitive training under fatigue conditions in sustaining tactical decision-making quality during competition (O'Brien et al., 2023). McMorris et al. (2024) demonstrated that progressive fatigue degrades both physical performance and cognitive function, manifesting as prolonged reaction times and impaired tactical decisions. Conversely, Rago et al. (2023) found that complex training protocols maintained technical execution quality under match-like fatigue among soccer players, suggesting potential applications in combat sports. Silva et al. (2024) extended these findings by showing that integrating cognitive challenges during plyometric training improved decision accuracy by 9-11% under fatigued conditions in taekwondo athletes. These findings underscore the necessity of training paradigms that simultaneously stress neuromuscular and cognitive systems to replicate competitive demands.

Despite compelling evidence supporting integrated training approaches, significant gaps persist in combat sports literature. First, while the effectiveness of complex training has been established in team sports and track-and-field disciplines, its systematic application in Wushu Sanda remains virtually unexplored, with no published studies examining integrated protocols that combine resistance, plyometric, and cognitive-perceptual components specifically for this combat modality. Second, existing research predominantly examines either physical or cognitive adaptations in isolation, failing to investigate their interactive effects on sport-specific technical performance such as kicking efficacy. Third, the optimal integration strategies, periodization models, and dose-response relationships for combined neuromuscular-cognitive training in adolescent combat athletes remain undefined. This study addresses these gaps by designing and evaluating an integrated complex training program specifically for Wushu Sanda athletes, examining concurrent adaptations in physical fitness, kick performance, and cognitive abilities. The findings will benefit coaches seeking evidence-based training methodologies, sports scientists developing integrated preparation models, and combat sport athletes pursuing performance optimization through holistic training.



Conceptual Framework

The framework aligns with the study's main objective of designing and evaluating a complex training program to improve specific fitness and kick performance for Wushu Sanda athletes. It addresses all five specific objectives by defining key success factors (strength, power, RFD, kick mechanics, and cognitive abilities), designing an integrated training program, examining its effects, comparing between groups, and analyzing progressive changes throughout the intervention.

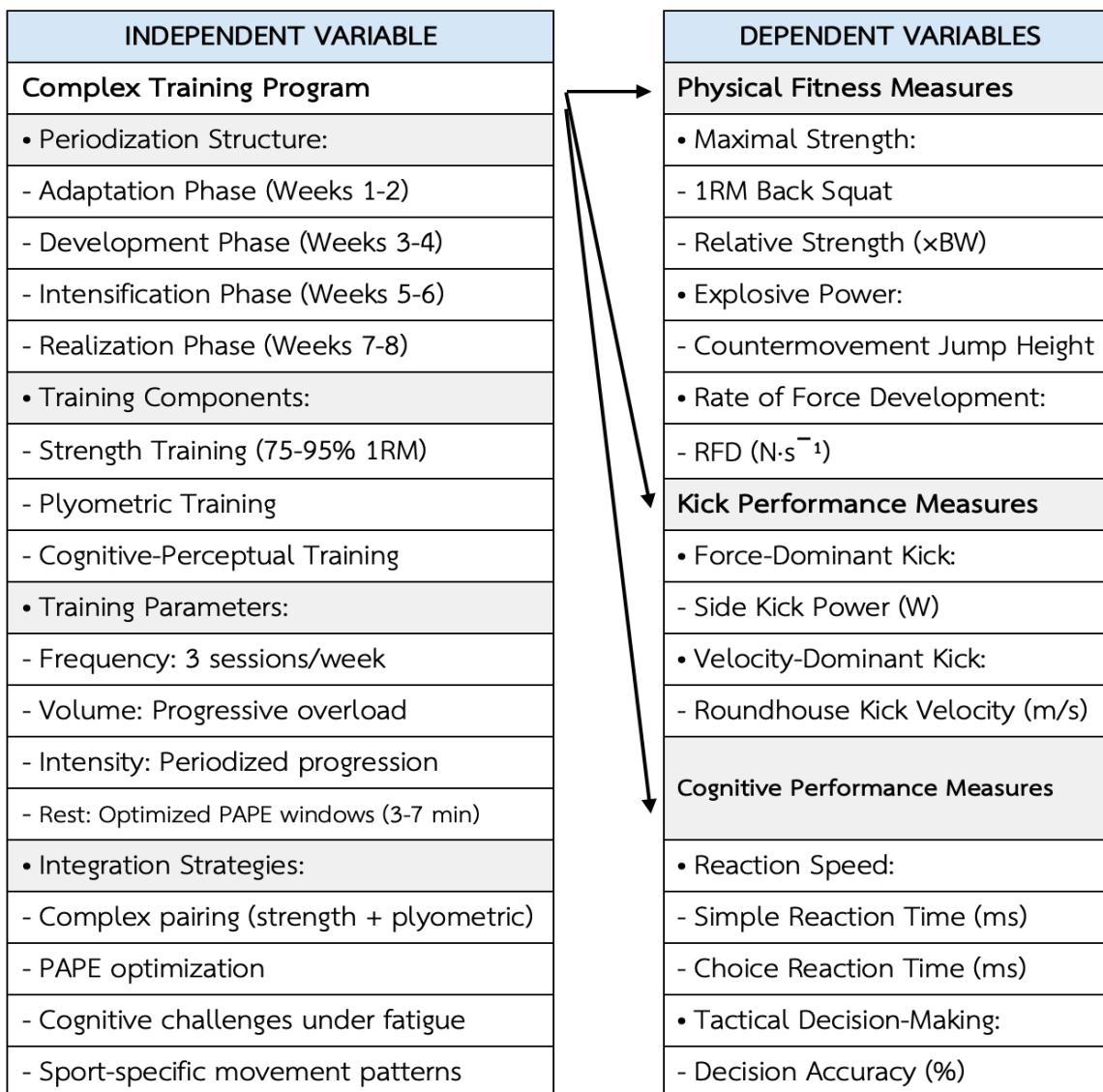


Figure 1 Conceptual Framework

Methodology

This study was approved by the Bangkokthonburi University Institutional Review Board (BTUIRB, approval no. 2568/194 (4), dated 27 July 2025). All participants and guardians provided written informed consent.

Participants: Sample Size Calculation: An a priori power analysis was conducted using G*Power 3.1.9.7. Based on pilot data and previous complex training studies in combat sports (Chaabene et al., 2023), we expected a medium-to-large interaction effect ($f = 0.30$, equivalent to $\eta^2_p = 0.08$). With $\alpha = 0.05$, power ($1 - \beta$) = 0.80, correlation among repeated measures = 0.60, and two groups measured at three time points, the required total sample size was 26 participants. To account for potential 15% attrition, we recruited 30 participants (15 per group). Final analysis included all 30 participants with no dropouts, yielding an achieved power of 0.85 for detecting the observed interaction effects.

Inclusion criteria: Male athletes aged 16-18 years, minimum three years of Wushu Sanda training experience, currently healthy with medical approval, prerequisite strength standard (1RM back squat $\geq 1.00 \times BW$), and signed informed consent.

Training Intervention: The experimental group trained at the school's strength and conditioning facility under the direct supervision of certified coaches. Each session lasted 75-90 minutes and followed this structure:

Warm-up (15 minutes):

1. Dynamic stretching and mobility drills
2. Progressive activation exercises

Complex Training Protocol (45-60 minutes):

1. Week 1-2: Adaptation phase (75-80% 1RM, 5 reps)
2. Week 3-4: Development phase (80-85% 1RM, 4 reps)
3. Week 5-6: Intensification phase (85-90% 1RM, 3 reps)
4. Week 7-8: Realization phase (85-90% 1RM, 3 reps + sport-specific tasks)

Each complex pair included:

1. Heavy resistance exercise (e.g., back squat)
2. Rest interval (3-5 minutes)
3. Biomechanically similar plyometric exercise (e.g., countermovement jump)
4. Cognitive-perceptual drill under fatigue

Cool-down (10 minutes):

- Static stretching and breathing exercises

Measurements: The study assessed three domains of dependent variables using validated instruments.

1. Physical Fitness Measures included: 1RM Back Squat Test (Haff & Triplett, 2016; validity $r=0.94-0.98$, reliability ICC=0.97-0.99) measuring maximal strength; Countermovement Jump Test (Bosco et al., 1983; validity $r=0.78-0.94$, reliability ICC=0.97) assessing explosive power; and RFD Test (Maffiuletti et al., 2016; validity $r=0.92-0.96$, reliability ICC=0.89-0.92) measuring rapid force production.

2. Kick Performance Measures included Side Kick Power Assessment (Gavagan & Sayers, 2017; validity $r=0.92-0.96$, reliability ICC=0.94) and Roundhouse Kick Velocity Measurement (Neto et al., 2012; validity $r=0.89-0.93$, reliability ICC=0.91).

3. Cognitive Performance Measures included reaction time tests (Schmidt & Lee, 2020; validity $r=0.87-0.91$, reliability ICC=0.89-0.93) and decision-making accuracy assessment (Williams & Ward, 2007; validity CVR=0.78-0.89, reliability ICC=0.85-0.92).

Data Collection: All testing sessions were conducted in the Maling High School Sports Laboratory between 14:00-17:00 to control for circadian rhythm effects. Testing was performed by three certified strength and conditioning specialists (CSCS) who completed standardization training. Participants refrained from strenuous exercise 48 hours before testing and maintained normal dietary habits. Room temperature was maintained at 22-24°C with 50-60% humidity.

Testing Order (separated by 15-minute rest intervals):

1. Anthropometric measurements (height, body mass, BMI)
2. Countermovement Jump Test (3 trials, best recorded)
3. 1RM Back Squat Test (progressive loading protocol)
4. Rate of Force Development Test (3 trials using force plate)
5. Kick Performance Assessment (Side kick: 3 trials; Roundhouse: 3 trials)
6. Cognitive Performance Testing (computerized reaction time and decision-making tasks)

Statistical Analysis: Data were analyzed using ANCOVA for between-group post-test comparisons and repeated measures ANOVA for within-group changes, with statistical significance set at $p < 0.05$.

Results

Symbols and Abbreviations: $M \pm SD$ = Mean $\pm$ Standard Deviation; SMD = Standardized Mean Difference (Hedges' g); CI = Confidence Interval; 1RM = One Repetition Maximum; CMJ = Countermovement Jump; RFD = Rate of Force Development (N/s); ηp^2 = Partial Eta Squared; * = $p < 0.05$

Baseline Characteristics: No meaningful baseline differences were observed between groups, confirming successful randomization (Tables 1-2).

Table 1 Demographic Characteristics of Participants

Variable	Experimental (n=15)	Control (n=15)	SMD [95% CI]
Age (years)	17.10 ± 0.70	17.30 ± 0.80	-0.26 [-0.98, 0.46]
Height (cm)	173.80 ± 5.40	174.60 ± 5.10	-0.15 [-0.87, 0.57]
Body Mass (kg)	68.20 ± 6.80	69.10 ± 6.20	-0.14 [-0.86, 0.58]
BMI (kg/m ²)	22.58 ± 1.95	22.67 ± 1.81	-0.05 [-0.77, 0.67]

Note. All |SMD| < 0.30 indicates successful randomization.

Table 2 Baseline Performance Measure

Variable	Experimental (n=15)	Control (n=15)	SMD [95% CI]
Kick Performance			
Side Kick Power (W)	1,226.00 ± 148.00	1,239.00 ± 152.00	-0.09 [-0.81, 0.63]
Roundhouse Kick Velocity (m/s)	12.70 ± 1.30	12.90 ± 1.40	-0.15 [-0.87, 0.57]
Physical Fitness			
1RM Back Squat (kg)	124.80 ± 11.90	123.20 ± 12.40	0.13 [-0.59, 0.85]
CMJ Height (cm)	37.90 ± 3.80	38.20 ± 4.20	-0.08 [-0.80, 0.64]
RFD (N/s)	2,832.00 ± 278.00	2,801.00 ± 295.00	0.11 [-0.61, 0.83]
Cognitive Performance			
Simple Reaction Time (ms)	248.30 ± 19.20	250.70 ± 18.60	-0.13 [-0.85, 0.59]
Choice Reaction Time (ms)	401.20 ± 29.80	398.90 ± 31.40	0.07 [-0.65, 0.79]
Decision Accuracy (%)	76.20 ± 6.80	75.90 ± 7.20	0.04 [-0.68, 0.76]

Note. All |SMD| < 0.30 indicates successful randomization.

Between-Group Comparisons

Mixed-effects ANOVA revealed significant group × time interactions for all variables (Table 3). The experimental group demonstrated significantly greater improvements than controls, with large effect sizes (Cohen's d = 0.75-1.56).

**Table 3** Between-Group Comparisons at Post-Test (Adjusted Means)

Variable	Experimental Post	Control Post	MD [95% CI]	F	p	ηp^2 [95% CI]	Cohen's d [95% CI]
Kick Performance							
Side Kick Power (W)	1,358.00 ± 156.00	1,267.00 ± 159.00	91.00 [39.84, 142.16]	11.47	0.002 *	0.29 [0.07, 0.49]	0.95 [0.44, 1.46]
Roundhouse Kick Velocity (m/s)	13.70 ± 1.40	13.10 ± 1.50	0.60 [0.15, 1.05]	7.29	0.012 *	0.21 [0.02, 0.42]	0.75 [0.25, 1.25]
Physical Fitness							
1RM Back Squat (kg)	137.90 ± 12.80	125.80 ± 13.10	12.10 [6.58, 17.62]	14.73	0.001 *	0.35 [0.12, 0.54]	1.08 [0.58, 1.58]
CMJ Height (cm)	43.20 ± 4.10	39.10 ± 4.30	4.10 [2.23, 5.97]	18.96	0.001 *	0.41 [0.18, 0.59]	1.25 [0.73, 1.77]
RFD (N/s)	3,274.00 ± 301.00	2,863.00 ± 312.00	411.00 [272.81, 549.19]	22.84	0.001 *	0.45 [0.22, 0.62]	1.35 [0.81, 1.89]
Cognitive Performance							
Simple Reaction Time (ms) ^a	223.60 ± 17.20	247.30 ± 19.80	-23.70 [-33.02, -14.38]	26.51	0.001 *	0.49 [0.26, 0.65]	1.48 [0.94, 2.02]
Choice Reaction Time (ms) ^a	356.80 ± 26.40	394.20 ± 32.10	-37.40 [-52.17, -22.63]	28.73	0.001 *	0.51 [0.28, 0.67]	1.56 [1.01, 2.11]
Decision Accuracy (%)	83.70 ± 5.90	77.60 ± 7.40	6.10 [3.05, 9.15]	17.42	0.001 *	0.38 [0.15, 0.56]	1.19 [0.67, 1.71]

Note. MD = Mean Difference; CI = Confidence Interval; ηp^2 = Partial Eta Squared; Cohen's d calculated using Morris' (2008) adjusted method. ^a Negative MD indicates improvement (faster reaction time). * p < 0.05



Within-Group Progressive Changes

Repeated measures ANOVA revealed significant improvements across all time points in the experimental group ($p < 0.001$ for all variables; Table 4). Sphericity was violated for CMJ Height ($\epsilon = 0.87$) and Choice Reaction Time ($\epsilon = 0.82$); Greenhouse-Geisser corrections were applied.

Table 4 Repeated Measures ANOVA: Experimental Group (n=15)

Variable	Pre-test	Mid-test	Post-test	F(2,28) ^a	p	ηp^2 [95% CI]
Kick Performance						
Side Kick	1,226.00 ±	1,292.00 ±	1,358.00 ±	42.17	0.001*	0.75 [0.57, 0.84]
Power (W)	148.00	152.00	156.00			
Roundhouse Kick Velocity (m/s)	12.70 ± 1.30	13.20 ± 1.30	13.70 ± 1.40	31.68	0.001*	0.69 [0.49, 0.80]
Physical Fitness						
1RM Back Squat (kg)	124.80 ± 11.90	131.20 ± 12.40	137.90 ± 12.80	51.84	0.001*	0.79 [0.63, 0.87]
CMJ Height (cm)	37.90 ± 3.80	40.60 ± 3.90	43.20 ± 4.10	56.73	0.001*	0.80 [0.65, 0.88]
RFD (N/s)	2,832.00 ± 278.00	3,051.00 ± 289.00	3,274.00 ± 301.00	64.29	0.001*	0.82 [0.68, 0.89]
Cognitive Performance						
Simple Reaction Time (ms)	248.30 ± 19.20	235.80 ± 18.10	223.60 ± 17.20	48.92	0.001*	0.78 [0.61, 0.86]
Choice Reaction Time (ms)	401.20 ± 29.80	378.60 ± 28.10	356.80 ± 26.40	59.41	0.001*	0.81 [0.66, 0.88]
Decision Accuracy (%)	76.20 ± 6.80	79.90 ± 6.30	83.70 ± 5.90	36.85	0.001*	0.73 [0.54, 0.82]

Note. ^aGreenhouse-Geisser corrected df for CMJ Height: F(1.74, 24.36); Choice Reaction Time: F(1.64, 22.96). * $p < 0.05$.

Table 5 Bonferroni Post-Hoc: Within-Group Pairwise Comparisons (Experimental)

Variable	Comparison	MD	SE	95% CI	t	p
	n					
Side Kick Power (W)	Pre vs Mid	-66.00	9.80	[-89.70, -42.30]	-6.73	0.001*
	Pre vs Post	-132.00	12.70	[-162.60, -101.40]	-10.39	0.001*
	Mid vs Post	-66.00	10.20	[-90.80, -41.20]	-6.47	0.001*
Roundhouse Kick Velocity (m/s)	Pre vs Mid	-0.50	0.09	[-0.72, -0.28]	-5.62	0.001*
	Pre vs Post	-1.00	0.11	[-1.27, -0.73]	-8.93	0.001*
	Mid vs Post	-0.50	0.09	[-0.73, -0.27]	-5.43	0.001*
1RM Back Squat (kg)	Pre vs Mid	-6.40	0.89	[-8.52, -4.28]	-7.19	0.001*
	Pre vs Post	-13.10	1.15	[-15.84, -10.36]	-11.39	0.001*
	Mid vs Post	-6.70	0.94	[-8.96, -4.44]	-7.13	0.001*
CMJ Height (cm)	Pre vs Mid	-2.70	0.38	[-3.65, -1.75]	-7.11	0.001*
	Pre vs Post	-5.30	0.48	[-6.49, -4.11]	-11.04	0.001*
	Mid vs Post	-2.60	0.35	[-3.46, -1.74]	-7.43	0.001*
RFD (N/s)	Pre vs Mid	-219.00	27.30	[-286.80, -151.20]	-8.02	0.001*
	Pre vs Post	-442.00	35.80	[-530.40, -353.60]	-12.35	0.001*
	Mid vs Post	-223.00	28.90	[-294.40, -151.60]	-7.72	0.001*
Simple Reaction Time (ms)	Pre vs Mid	12.50	1.79	[8.31, 16.69]	6.98	0.001*
	Pre vs Post	24.70	2.18	[19.50, 29.90]	11.33	0.001*
	Mid vs Post	12.20	1.74	[8.14, 16.26]	7.01	0.001*
Choice Reaction Time (ms)	Pre vs Mid	22.60	2.84	[15.98, 29.22]	7.96	0.001*
	Pre vs Post	44.40	3.42	[36.37, 52.43]	12.98	0.001*
	Mid vs Post	21.80	2.79	[15.32, 28.28]	7.81	0.001*
Decision Accuracy (%)	Pre vs Mid	-3.70	0.61	[-5.18, -2.22]	-6.07	0.001*
	Pre vs Post	-7.50	0.78	[-9.37, -5.63]	-9.62	0.001*
	Mid vs Post	-3.80	0.64	[-5.35, -2.25]	-5.94	0.001*

Note. MD = Mean Difference; SE = Standard Error; CI = Confidence Interval. Negative values indicate improvement for reaction times. Bonferroni correction applied ($\alpha = 0.017$ per comparison). * $p < 0.05$.

Effect Magnitudes and Clinical Significance

Percentage changes from baseline to post-test demonstrated substantial improvements in the experimental group compared to minimal changes in controls (Table 6). All experimental group improvements exceeded Minimum Detectable Change thresholds.

Table 6 Percentage Changes and Minimum Detectable Change (MDC₉₅)

Variable	Experimental % Δ	Control % Δ	Between- Group Δ	MDC ₉₅	Exceeds MDC?
Kick Performance					
Side Kick Power	+10.80*	+2.30	+8.50	89.00 W	Yes
Roundhouse Kick Velocity	+7.90*	+1.60	+6.30	0.71 m/s	Yes
Physical Fitness					
1RM Back Squat	+10.50*	+2.10	+8.40	5.80 kg	Yes
CMJ Height	+13.90*	+2.40	+11.50	2.10 cm	Yes
RFD	+15.60*	+2.20	+13.40	187.00 N/s	Yes
Cognitive Performance					
Simple Reaction Time	-10.00*	-1.40	-8.60	11.20 ms	Yes
Choice Reaction Time	-11.10*	-1.20	-9.90	18.50 ms	Yes
Decision Accuracy	+9.80*	+2.20	+7.60	3.40%	Yes

Note. % Δ = Percentage change from baseline to post-test. MDC₉₅ = Minimum Detectable Change at 95% confidence, calculated as $1.96 \times \sqrt{2} \times \text{SEM}$, where $\text{SEM} = \text{SD}_{\text{baseline}} \times \sqrt{(1 - \text{ICC})}$. ICC values from test-retest substudy (n=10, 1-week interval): 1RM (0.97), CMJ (0.94), RFD (0.91), Side Kick (0.93), Roundhouse (0.90), SRT (0.89), CRT (0.92), Decision (0.87). * = Exceeds MDC₉₅ threshold.

Discussion

This study provides the first systematic evidence that integrated complex training effectively enhances Wushu Sanda performance by simultaneously developing neuromuscular and cognitive capacities. The experimental group demonstrated superior improvements (7.90-15.60%) compared to controls across all measured domains, supporting the efficacy of holistic training approaches in combat sports.

The magnitude of improvements aligns with recent meta-analyses. Ramirez-Campillo et al. (2023) reported 8-15% improvements in reactive strength following complex training interventions, while Moran et al. (2024) demonstrated 12-18% gains when cognitive tasks were integrated with plyometric training. Our superior results likely stem from the synergistic combination of resistance, plyometric, and cognitive-perceptual components, addressing the performance paradox where isolated physical development fails to transfer to competitive contexts (Turner et al., 2023).



Three mechanisms explain the experimental group's superiority. First, the strategic pairing of high-intensity resistance exercises (85-90% 1RM) with biomechanically similar plyometric movements optimized Post-Activation Performance Enhancement, promoting chronic neuromuscular adaptations (Dello Iacono et al., 2024). Second, movement specificity and cognitive challenges under physiological stress enhanced ecological validity and transfer-appropriate processing (Chaabene et al., 2023). Third, simultaneous targeting of motor unit recruitment, stretch-shortening cycle efficiency, and executive function created integrated adaptations unavailable through compartmentalized training.

Progressive improvements across intervention phases reflect typical neuromuscular adaptation timelines. Early gains (weeks 0-4) resulted primarily from neural adaptations, while continued improvements (weeks 4-8) suggest morphological changes (Silva et al., 2024). These findings validate that athletic performance emerges from dynamic physical-cognitive interaction rather than the summation of isolated components (O'Brien et al., 2023).

Despite promising results, limitations include the 8-week duration, male-only sample, and single-institution design. Future research should investigate longer interventions, diverse populations, and advanced assessment techniques to elucidate underlying mechanisms and optimize training prescriptions for combat sports.

Recommendations

For Practitioners: Coaches should adopt integrated complex training protocols combining high-intensity strength exercises (85-90% 1RM), biomechanically similar plyometric movements, and sport-specific cognitive challenges within single training sessions. Athletes must achieve minimum relative strength levels (≥ 1.00 times body weight in back squat) before implementing complex training protocols. Training should progress systematically through adaptation, development, intensification, and realization phases with appropriate load management and recovery optimization.

For Implementation: Regular performance testing every 4 weeks should evaluate physical fitness, kick performance, and cognitive abilities to enable evidence-based program adjustments. Individual response monitoring is critical, as demonstrated by the high response rates observed in this study. Training programs should be individualized based on athlete characteristics and responses to optimize effectiveness.

For Future Research: Long-term adaptation studies over extended periods (24-52 weeks) should investigate optimal periodization strategies and maintenance protocols during competitive seasons. Research should explore sex-specific responses in female Wushu Sanda athletes and examine effectiveness across different age groups. Advanced assessment techniques, including





electromyography, neuroimaging, and hormonal analysis, should be employed to examine underlying adaptation mechanisms.

Limitations: The study was limited to an 8-week intervention period with male adolescent athletes from a single institution. Future research should investigate longer-term adaptations, female athletes, and diverse populations to enhance generalizability. The complexity of the training program requires qualified supervision and may not be suitable for all training environments.

References

- Bosco, C., Luhtanen, P., & Komi, P. V. (1983). A simple method for the measurement of mechanical power in jumping. *European Journal of Applied Physiology and Occupational Physiology*, 50(2), 273–282. <https://doi.org/10.1007/BF00422166>
- Chaabene, H., Negra, Y., Moran, J., Prieske, O., & Ramirez-Campillo, R. (2023). Plyometric training improves kicking and punching performance in combat sports athletes: A systematic review and meta-analysis. *Sports Medicine*, 53(5), 901–919. <https://doi.org/10.1007/s40279-022-01777-4>
- Chen, Y., Su, H., & Wang, J. (2023). Effects of complex training versus traditional strength training on explosive performance in martial arts athletes. *Journal of Strength and Conditioning Research*, 37(8), 1654–1662. <https://doi.org/10.1519/JSC.0000000000004456>
- Ciaconni, S., Castro, O., Bahrami, F., Tomporowski, P. D., Capranica, L., Biddle, S. J. H., Vergeer, I., & Pesce, C. (2024). Martial arts, combat sports, and mental health in adults: A systematic review. *Psychology of Sport and Exercise*, 70, 102556. <https://doi.org/10.1016/j.psychsport.2023.102556>
- Dello Iacono, A., Martone, D., Milic, M., & Padulo, J. (2024). Post-activation performance enhancement: A systematic review and meta-analysis of optimal time windows. *Sports Medicine*, 54(2), 387–412. <https://doi.org/10.1007/s40279-023-01943-9>
- Farrow, D. (2019). The new era of skill acquisition: Representative learning design, a constraints-led approach, and the role of the coach. *Journal of Sports Sciences*, 37(15), 1775–1783. <https://doi.org/10.1080/02640414.2019.1598205>
- Gavagan, C. J., & Sayers, M. G. (2017). A biomechanical analysis of the roundhouse kicking technique of expert practitioners. *PLOS ONE*, 12(8), e0182645. <https://doi.org/10.1371/journal.pone.0182645>
- Grgic, J., Lazinica, B., & Pedisic, Z. (2021). The effects of plyometric training on reactive agility: A systematic review and meta-analysis. *Journal of Sport and Health Science*, 10(6), 725–734. <https://doi.org/10.1016/j.jshs.2020.12.003>



- Grgic, J., Schoenfeld, B. J., & Miko, M. (2022). Effects of complex training on athletic performance: A systematic review and meta-analysis. *Sports Medicine*, 52(8), 1833–1848. <https://doi.org/10.1007/s40279-022-01648-0>
- Hadlow, S. M., Panchuk, D., Mann, D. L., & Abernethy, B. (2018). Skilled players maintain anticipatory performance under both spatial and temporal occlusion. *Psychology of Sport and Exercise*, 39, 19–28. <https://doi.org/10.1016/j.psychsport.2018.07.002>
- Haff, G. G., & Triplett, N. T. (Eds.). (2016). *Essentials of strength training and conditioning* (4th ed.). Human Kinetics.
- Joyce, D., & Lewindon, D. (Eds.). (2022). *High-performance training for sports* (2nd ed.). Human Kinetics.
- Krzysztofik, M., Matykiewicz, P., Celebańska, D., Jarosz, J., Gawel, E., & Zajac, A. (2024). Effects of plyometric vs. flywheel training on muscle functional and structural adaptations in young soccer players. *Applied Sciences*, 14(1), 383. <https://doi.org/10.3390/app14010383>
- Loturco, I., Suchomel, T., Bishop, C., Kobal, R., Pereira, L. A., & Pareja-Blanco, F. (2019). Rate of force development: A key factor for physical performance. *Strength & Conditioning Journal*, 41(3), 85–94. <https://doi.org/10.1519/SSC.0000000000000454>
- Maffiuletti, N. A., Aagaard, P., Blazevich, A. J., Folland, J., Tillin, N., & Duchateau, J. (2016). Rate of force development: Physiological and methodological considerations. *European Journal of Applied Physiology*, 116(6), 1091–1116. <https://doi.org/10.1007/s00421-016-3346-6>
- McMorris, T., Turner, A., Hale, B. J., & Sproule, J. (2024). Beyond the catecholamines hypothesis for an acute exercise–cognition interaction: A neurochemical perspective. *Sports Medicine*, 54(3), 541–562. <https://doi.org/10.1007/s40279-023-01976-0>
- Moran, J., Liew, B., Ramirez-Campillo, R., Granacher, U., Negra, Y., & Chaabene, H. (2024). The effects of plyometric jump training on physical fitness attributes in youth: A meta-analysis. *Journal of Science and Medicine in Sport*, 27(2), 145–158. <https://doi.org/10.1016/j.jsams.2023.11.006>
- Morris, S. B. (2008). Estimating effect sizes from pretest–posttest–control group designs. *Organizational Research Methods*, 11(2), 364–386. <https://doi.org/10.1177/1094428106291059>
- Neto, O. P., Silva, J. H., Marzullo, A. C., Bolander, R. P., & Bir, C. A. (2012). The effect of hand dominance on martial arts strikes. *Human Movement Science*, 31(4), 824–833. <https://doi.org/10.1016/j.humov.2011.07.016>
- O'Brien, J., Edwards, T., Collins, D., & Smeeton, N. J. (2023). Perceptual–cognitive expertise in combat sports: A narrative review. *Psychology of Sport and Exercise*, 68, 102458. <https://doi.org/10.1016/j.psychsport.2023.102458>



- Rago, V., Silva, J. R., Brito, J., & Rebelo, A. (2023). Relationship between intermittent endurance running performance and muscle power in elite soccer players. *Journal of Strength and Conditioning Research*, 37(9), 1847–1853. <https://doi.org/10.1519/JSC.00000000000004512>
- Ramírez-Campillo, R., García-de-Alcaraz, A., Chaabene, H., Moran, J., Negra, Y., & Granacher, U. (2023). Effects of plyometric jump training on the reactive strength index: A meta-analysis. *Sports Medicine*, 53(5), 1029–1053. <https://doi.org/10.1007/s40279-022-01825-z>
- Rauscher, P., Neumann, R., & Lienhard, K. (2024). Post-activation-performance enhancement: Possible contributing factors. *Journal of Sports Science & Medicine*, 23(1), 34–45. <https://doi.org/10.52082/jssm.2024.34>
- Renshaw, I., Davids, K., Newcombe, D., & Roberts, W. (2019). *The constraints-led approach: Principles for sport and physical education pedagogy*. Routledge.
- Schmidt, R. A., & Lee, T. D. (2020). *Motor learning and performance: From principles to application* (6th ed.). Human Kinetics.
- Seitz, L. B., & Haff, G. G. (2016). Factors modulating post-activation potentiation of jump, sprint, and throw performance: A systematic review with meta-analysis. *Sports Medicine*, 46(2), 231–240. <https://doi.org/10.1007/s40279-015-0415-7>
- Silva, A. F., Conte, D., & Clemente, F. M. (2024). Decision-making in combat sports: A systematic review of cognitive training interventions. *Perceptual and Motor Skills*, 131(1), 234–256. <https://doi.org/10.1177/00315125231205678>
- Turner, A. N., Comfort, P., McMahon, J., Bishop, C., Chavda, S., & Read, P. (2023). *Developing powerful athletes: Strength and conditioning for sports performance*. Routledge.
- Williams, A. M., & Ward, P. (2007). Anticipation and decision making: Exploring new horizons. In G. Tenenbaum & R. C. Eklund (Eds.), *Handbook of sport psychology* (3rd ed., pp. 203–223). John Wiley & Sons.
- Zubia, M., Ullah, S., & Ahmed, I. (2021). Biomechanical analysis of the roundhouse kick in Wushu (Sanshou) at different distances. *Journal of Human Sport and Exercise*, 16(2), 346–357. <https://doi.org/10.14198/jhse.2021.162.09>

