High-Intensity Interval Training and Its Impact on Biomotor Components in Wushu Athletes: A Systematic Review

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Abstract. Wushu, a traditional Chinese martial art, requires the integration of multiple biomotor capacities, including muscular strength, explosive power, speed, agility, flexibility, and both aerobic and anaerobic endurance. In recent years, High-Intensity Interval Training (HIIT) has gained considerable attention as a time-efficient training strategy capable of simultaneously enhancing these physiological attributes. This systematic review aims to critically evaluate the effectiveness of HIIT interventions in improving biomotor performance among wushu athletes. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [1]. A comprehensive literature search was performed across PubMed, Google Scholar, and ScienceDirect databases up to October 2025. Inclusion criteria comprised empirical studies involving wushu athletes, implementation of HIIT protocols, and assessment of at least one biomotor component. From an initial pool of 2,211 records, 10 studies satisfied the eligibility criteria following screening and quality appraisal. The synthesis of findings indicates that HIIT interventions produce significant improvements in maximal oxygen uptake (VO_2max), anaerobic capacity, muscular strength, power output, sprint performance, and agility. These outcomes are consistent with current sport science evidence suggesting that HIIT enhances both central (cardiorespiratory) and peripheral (neuromuscular) adaptations through repeated bouts of high-intensity effort interspersed with recovery periods [2], [3]. However, the impact of HIIT on dynamic balance remains inconclusive, likely due to variations in protocol design, training duration, and measurement instruments. In conclusion, HIIT represents an effective and practical training modality for optimizing key biomotor components in wushu athletes, particularly those associated with performance intensity and rapid movement execution. Future research should focus on standardized intervention protocols and explore its long-term effects on technical performance and injury prevention within the context of combat sports.

Keywords: Wushu; High-Intensity Interval Training (HIIT); Biomotor Components; VO_2max; Sport Performance; Systematic Review.

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1 Introduction

Wushu, widely recognized as Kung Fu, is a traditional Chinese martial art comprising two principal competitive formats: Taolu and Sanda. Taolu emphasizes choreographed routines evaluated based on technical precision, coordination, speed, flexibility, and strength, whereas Sanda represents a full-contact combat discipline involving striking and grappling techniques performed in structured bouts, typically consisting of three rounds of two minutes each with one-minute recovery intervals [1]. These contrasting formats impose distinct physiological and biomechanical demands. Taolu primarily requires refined neuromuscular coordination, flexibility, and postural control, while Sanda necessitates rapid force production, reaction speed, and high tolerance to anaerobic fatigue [2], [3].

Biomotor components constitute the fundamental determinants of athletic performance and are governed by the interaction of neuromuscular, cardiorespiratory, and metabolic systems. Core biomotor attributes include muscular strength, speed, endurance, coordination, flexibility, agility, balance, reaction time, accuracy, and explosive power [4]. In the context of wushu, particularly Sanda, empirical evidence suggests that athletes often exhibit suboptimal biomotor profiles relative to the sport's physiological demands. For instance, a field study conducted among Sanda athletes in Indonesia reported that 72% of participants demonstrated insufficient upper-body strength and explosive power, while 48% exhibited critically low flexibility levels [5]. Similarly, assessments of wushu athletes in Bali revealed inadequate power output and maximal oxygen uptake (VO_2max), indicating limited aerobic capacity [6]. These findings highlight a substantial discrepancy between performance requirements and athletes' physical preparedness, thereby underscoring the need for targeted and efficient training interventions.

High-Intensity Interval Training (HIIT) has emerged as a scientifically supported training modality characterized by repeated bouts of high-intensity exercise (typically ≥80% of maximal heart rate) interspersed with periods of active or passive recovery [7]. Compared to moderate-intensity continuous training, HIIT has demonstrated superior efficacy in improving VO_2max, accelerating heart rate recovery, and enhancing energy expenditure within shorter training durations [8]. From a physiological perspective, HIIT promotes mitochondrial biogenesis, enhances buffering capacity against metabolic acidosis, and optimizes recruitment of type II (fast-twitch) muscle fibers, which are critical for explosive and high-intensity movements characteristic of wushu performance [9], [10].

Within combat sports, growing evidence supports the effectiveness of HIIT in enhancing both aerobic and anaerobic performance. Previous systematic reviews have reported improvements in VO_2max ranging from 4.4% to 23.0% among athletes in disciplines such as judo, taekwondo, and boxing [11], [12]. Despite these advances, the application of HIIT specifically in wushu remains underexplored, largely due to the limited availability of sport-specific empirical studies. This gap is particularly relevant given the unique demands of wushu, including asymmetrical movement patterns, complex motor coordination, dynamic balance, and the integration of aesthetic and combat elements.

Preliminary investigations suggest promising outcomes. A pilot study implementing a Sanda-specific HIIT protocol—structured as three rounds of two minutes with intermittent work-rest intervals (15:5:5 seconds)—demonstrated significant improvements in neuromuscular performance, aerobic capacity, and anaerobic endurance [13]. Furthermore, the development of biomotor-oriented HIIT programs has been shown to significantly enhance lower-body strength, core stability, speed, and agility, although improvements in balance were not consistently observed [9]. These findings indicate that while HIIT is effective in targeting several key biomotor attributes, its impact may vary depending on the specific component being trained.

Given these inconsistencies and the limited synthesis of evidence specific to wushu, a systematic evaluation is warranted. Therefore, this study aims to critically examine the effectiveness of HIIT interventions in improving biomotor performance in wushu athletes, with particular attention to both physiological adaptations and sport-specific performance outcomes.

2 Methods

This systematic review was designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure transparency, reproducibility, and methodological rigor in the identification, selection, and synthesis of relevant studies [1].

2.1 Study Design

A systematic review design was employed to synthesize empirical evidence regarding the effects of High-Intensity Interval Training (HIIT) on biomotor performance in wushu athletes. A quantitative meta-analysis was not conducted due to substantial heterogeneity among the included studies, particularly in terms of intervention protocols, participant characteristics, training duration, and outcome variables. Such variability limits statistical pooling and may compromise the validity of aggregated effect sizes [2]. Therefore, a qualitative synthesis approach was adopted to enable a comprehensive and context-sensitive interpretation of findings.

2.2 Data Sources and Search Strategy

A structured literature search was conducted across three major electronic databases: PubMed, ScienceDirect, and Google Scholar. The search covered studies published up to March 2026. A Boolean search strategy was applied to maximize retrieval sensitivity and specificity, combining population- and intervention-related keywords as follows: (“wushu” OR “kung fu” OR “sanda” OR “taolu”) AND (“high-intensity interval training” OR “HIIT” OR “interval training” OR “sprint interval training” OR “repeated sprint training”).

The search strategy was adapted from established systematic reviews in sport science to ensure methodological consistency and coverage [3]. Additionally, reference lists of

selected articles were manually screened to identify potentially relevant studies not captured through database searching.

2.3 Eligibility Criteria

Studies were selected based on predefined inclusion and exclusion criteria to ensure relevance and methodological consistency.

Inclusion criteria comprised:

(1) peer-reviewed original research articles;

(2) participants identified as wushu athletes, regardless of age, sex, or competitive level;

(3) implementation of HIIT protocols, either as a primary intervention or combined with other training modalities;

(4) assessment of at least one biomotor component (e.g., strength, power, speed, agility, flexibility, endurance, or body composition);

(5) reporting of quantitative outcomes;

(6) publication in English or Indonesian.

Exclusion criteria included:

(1) review articles, conference abstracts, case reports, and editorials;

(2) studies not involving wushu athletes;

(3) interventions without a defined HIIT component;

(4) studies lacking a control group or pre–post experimental design;

(5) incomplete or insufficient data for analysis.

2.4 Study Selection Process (PRISMA)

The study selection process followed the PRISMA flow framework. Two independent reviewers conducted the screening of titles and abstracts to identify potentially eligible studies. Full-text articles were subsequently assessed against the inclusion criteria. Any discrepancies between reviewers were resolved through discussion, and when necessary, consultation with a third reviewer to ensure objectivity and minimize selection bias [1].

2.5 Data Extraction

Data extraction was performed using a standardized and structured template to ensure consistency across studies. The following variables were collected: author(s) and year of publication; study design; participant characteristics (sample size, age, sex, and competition level); details of the HIIT protocol (training frequency, intensity, duration, and work-to-rest ratio); characteristics of comparison groups; outcome measures related to biomotor performance; and principal findings. This approach facilitates systematic comparison and synthesis of results across heterogeneous studies [4].

2.6 Methodological Quality Assessment

The methodological quality and reporting standards of the included studies were evaluated using the Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX) scale, which is specifically designed for exercise-based research [5]. The instrument consists of 12 criteria assessing study quality (maximum score = 12), including randomization, blinding, exercise adherence, and outcome reporting. Two reviewers independently conducted the assessment, and discrepancies were resolved through consensus to ensure reliability of the evaluation process.

3 Results

3.1 Study Selection

The systematic search initially identified 2,211 records across the selected databases. After removing duplicates, 1,895 studies were subjected to title and abstract screening, resulting in the exclusion of 1,870 articles that did not meet the predefined criteria. The full texts of 25 studies were then evaluated for eligibility. Of these, 15 articles were excluded due to the absence of HIIT interventions (n = 6), non-wushu participants (n = 5), lack of relevant outcome variables (n = 3), or incomplete data (n = 1). Ultimately, 10 studies were included in the qualitative synthesis.

3.2 Study Characteristics

The included studies were published between 2019 and 2025 and involved a total of 478 wushu athletes, with sample sizes ranging from 13 to 60 participants. The participants represented diverse competitive levels, from junior to elite athletes, and included both male and female cohorts. Methodologically, the studies consisted of randomized controlled trials (n = 3), quasi-experimental designs (n = 5), and pilot studies (n = 2). The duration of HIIT interventions ranged from 4 to 12 weeks, with training frequencies typically between two and three sessions per week, reflecting common conditioning practices in combat sports.

3.3 Effects of HIIT on Biomotor Components

Aerobic Capacity (VO_2max)

All included studies consistently reported significant improvements in aerobic capacity following HIIT interventions. Evidence from combat sports literature indicates that HIIT can increase VO_2max or VO_2peak by approximately 4.4% to 23.0%, depending on training duration and athlete level [1]. In addition, pooled data from combat sport athletes demonstrated a mean improvement of 2.83 $mL \cdot kg^{-1} \cdot min^{-1}$ (95% CI: 0.40–5.25; $p < 0.001$), indicating a clinically meaningful enhancement in cardiorespiratory fitness [2]. These adaptations are attributed to increased stroke volume, mitochondrial density, and oxidative enzyme activity.

Anaerobic Power and Capacity

HIIT demonstrated a robust and consistent effect on anaerobic performance. Several studies reported significant improvements in anaerobic power output and capacity following structured HIIT programs. For instance, an 8-week sport-specific HIIT intervention in adolescent wushu athletes resulted in significantly higher anaerobic power (9.74 ± 0.15 W·kg^{-1}) compared to the control group (8.93 ± 0.11 W·kg^{-1}; $p < 0.001$).

These findings are supported by physiological mechanisms such as enhanced phosphocreatine resynthesis, improved glycolytic enzyme activity, and increased buffering capacity against metabolic acidosis [3].

Muscular Strength, Power, Speed, and Agility

HIIT-based training, particularly when integrated into circuit-based or sport-specific protocols, was shown to significantly improve multiple neuromuscular components. Significant gains were observed in lower-body strength, core stability, explosive power, speed, and agility ($p < 0.001$) . These improvements are likely mediated by increased motor unit recruitment, enhanced rate of force development, and improved neuromuscular coordination [4]. Importantly, HIIT protocols incorporating wushu-specific movements (e.g., punches, kicks, and footwork) appear to yield greater performance transfer compared to generalized conditioning programs.

Balance

In contrast, the effect of HIIT on balance performance remains inconclusive. Several studies reported no statistically significant improvements in balance ($p = 0.840$), suggesting that HIIT alone may be insufficient to stimulate proprioceptive and postural adaptations . This limitation may be attributed to the predominantly linear and high-intensity nature of HIIT exercises, which do not adequately challenge the sensory-motor systems responsible for balance control.

Summary of HIIT Protocol Characteristics

The HIIT protocols varied across studies in terms of intensity, duration, and work-to-rest ratios. Common features included work intervals of 10–30 seconds, ratios ranging from 1:1 to 2:1, and intensities between 80% and 95% of maximal heart rate. Notably, sport-specific HIIT protocols that replicate match demands—such as intermittent striking, kicking, and footwork sequences—demonstrated superior effectiveness compared to generic protocols, highlighting the importance of training specificity.

4 Discussion

The present findings confirm that HIIT is a highly effective training modality for improving key biomotor components in wushu athletes, particularly aerobic and

anaerobic capacity. Improvements in VO_2max represent one of the most consistent outcomes, aligning with previous meta-analyses reporting significant increases in combat sport populations. For example, pooled data from multiple studies indicate a mean VO_2max increase of 2.83 $mL \cdot kg^{-1} \cdot min^{-1}$ (95% CI: 0.40–5.25; $p < 0.001$), reflecting meaningful physiological adaptation [2].

Furthermore, another systematic review reported a large effect size (ES = 1.007; 95% CI: 0.701–1.312; $p < 0.001$) for HIIT compared to control or moderate-intensity continuous training (MICT), indicating its superior effectiveness in enhancing aerobic fitness [5]. According to Cohen's classification, this magnitude represents a substantial improvement, reinforcing the role of HIIT as a time-efficient alternative to traditional endurance training.

From a sport science perspective, the superior effectiveness of HIIT can be explained through both central and peripheral adaptations. Centrally, HIIT enhances cardiac output and oxygen delivery, while peripherally, it increases mitochondrial density and improves muscle oxidative capacity [3], [6]. These adaptations are particularly relevant for wushu athletes, who require rapid transitions between high-intensity bursts and recovery phases during competition.

An important finding of this review is the enhanced effectiveness of sport-specific HIIT protocols. Training programs that integrate technical elements of wushu—such as punching combinations, kicking sequences, and dynamic footwork—demonstrate greater ecological validity and performance transfer. This observation is consistent with the principle of specificity, which posits that training adaptations are maximized when exercise closely replicates the movement patterns and energy demands of the sport [7]. Therefore, designing HIIT protocols that simulate match conditions is essential for optimizing performance outcomes.

Despite these benefits, the limited effect of HIIT on balance highlights a critical gap. Balance is a complex motor skill influenced by vestibular, proprioceptive, and visual systems, which may not be sufficiently stimulated by high-intensity interval protocols alone. Consequently, incorporating complementary training modalities, such as proprioceptive or neuromuscular training, may be necessary to address this limitation.

Overall, the findings of this review support the integration of HIIT into wushu training programs as an efficient and evidence-based approach to enhancing biomotor performance. However, future research should focus on standardizing intervention protocols, increasing sample sizes, and exploring long-term adaptations to provide more robust and generalizable evidence.

5 Conclusion

The present systematic review provides consistent evidence that High-Intensity Interval Training (HIIT) is an effective and time-efficient training modality for enhancing key physiological and biomotor attributes in combat sports athletes, including those engaged in wushu. In particular, improvements in aerobic capacity, as reflected by significant increases in maximal oxygen uptake (VO_2max), represent one of the most robust outcomes across the analyzed studies. These findings are supported by prior meta-

analytical evidence demonstrating that HIIT induces substantial cardiorespiratory adaptations, often exceeding those achieved through moderate-intensity continuous training (MICT) [1], [2].

From a physiological standpoint, the superiority of HIIT can be attributed to its ability to simultaneously stimulate central adaptations, such as increased cardiac output and oxygen delivery, and peripheral adaptations, including enhanced mitochondrial function and muscle oxidative capacity [3]. These mechanisms are particularly relevant in combat sports, where athletes must sustain repeated high-intensity efforts interspersed with short recovery periods.

Importantly, the integration of sport-specific movement patterns within HIIT protocols—such as striking combinations, kicking sequences, and dynamic footwork in wushu—appears to further enhance training effectiveness. This observation aligns with the principle of training specificity, which emphasizes that performance adaptations are maximized when exercise stimuli closely replicate the technical and physiological demands of competition [4]. Consequently, sport-specific HIIT protocols offer greater ecological validity and transferability to competitive performance compared to generalized conditioning approaches.

Despite these advantages, the current evidence also indicates variability in the responsiveness of certain biomotor components, particularly balance, suggesting that HIIT alone may not fully address all performance dimensions. Therefore, future training models should consider integrating complementary modalities, such as neuromuscular and proprioceptive training, to achieve a more comprehensive development of athletic performance.

In summary, HIIT represents a scientifically grounded and practically applicable training strategy for optimizing aerobic performance and overall biomotor capacity in wushu and other combat sports. Future research is recommended to establish standardized HIIT protocols, examine long-term adaptations, and further explore sport-specific applications to enhance both performance outcomes and injury prevention.

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