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The Role of Inhibitory Control in Taekwondo Performance: A Scoping Review

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Abstract:Objective: This study investigates the factors influencing taekwondo performance and explores diversified training strategies to foster athletes' holistic development. **Methods:**A scoping review was conducted following the PRISMA-ScR guidelines. Literature was systematically retrieved from PubMed, Web of Science, and CNKI databases, with the PICO framework informing the inclusion criteria. Results: Elite taekwondo athletes exhibit significantly enhanced executive functions, particularly inhibitory control, compared to novices or non-athletes. Taekwondo training effectively improves inhibitory control, a capacity that is closely correlated with rapid decision-making, tactical adjustments, and emotional regulation during competition. **Conclusion:** Integrating psychological skills and cognitive function training into systematic physical conditioning and technical development is essential for optimizing competitive performance and ensuring psychological stability in athletes.

Keywords: athletic performance, taekwondo, physical fitness, sport-specific skills, mental skills, cognitive function

Introduction

Taekwondo originated in Korea and has gained immense popularity worldwide since becoming an official Olympic sport in 2000. To enhance spectator appeal, the World Taekwondo Federation has revised its rules in recent years, replacing traditional manual scoring with electronic protective gear that senses strike intensity. This change has not only increased the scoring value of kicks but also prompted significant shifts in training and tactics: athletes must transition from single, low-frequency high kicks to complex, high-frequency attacks; coaches must move from closed training to data-driven scientific analysis to help athletes adapt flexibly to different opponents and unexpected situations during competition[1].

Therefore, employing methods from sports science to enhance athletic performance [2]. Taekwondo falls within the skill-dominant category of competitive disciplines. As an environment-dominant attentional sport, athletes require considerable attentional breadth, strong attentional shifting abilities, and sound information processing capabilities. Both inhibitory control and emotional arousal exhibit characteristics that guide attentional bias and enhance search efficiency [3]. Historically, much taekwondo training has emphasised the assessment of athletes' physical attributes and fitness levels [4], often overlooking the influence of psychological factors on performance.

With the rapid advancement of sports psychology, coaches and researchers have increasingly prioritised athletes' mental states, paying particular attention to the relationship between sport and cognitive function and its potential application in competitive training [5, 6]. The objective is to assist athletes in achieving peak performance within complex competitive environments [7]. Research indicates that high-level athletes typically demonstrate superior cognitive abilities compared to lower-level counterparts, while also revealing a close association between cognitive function and athletic performance [8]. Research employing the Go/Nogo experimental paradigm has found that reaction times to Go stimuli serve as behavioural indicators for assessing participants' overt responses. A significant group main effect was observed in reaction times to Go stimuli: taekwondo experts exhibited shorter reaction times than novices under both valid and invalid cue conditions, indicating superior reaction speed[9]. Comparisons of cognitive function between taekwondo experts and novices revealed superior inhibitory control in experts [10].

Therefore, exploring cognitive function issues contributes to the holistic development of taekwondo athletes. With the increasing volume of research linking sport and cognitive neuroscience, scientists are also attempting to integrate the principles of cognitive training into the field of sports science [11]. It is hoped that effective cognitive training models to enhance athletic performance and the most predictive assessment methods can be developed, laying a crucial foundation for future talent cultivation and selection. However, although this research topic has been widely discussed in the field of sports science, most studies in taekwondo remain confined to traditional psychological issues such as imagery training and self-talk skills within mental skills [12], with relatively scarce research and discussion on brain cognitive functions. In light of this, to further investigate the relationship between taekwondo techniques and cognitive functions, this study employs a literature review to elucidate the impact of inhibitory control on taekwondo athletes' performance and its applicable contexts. It aims to integrate cognitive science principles into taekwondo training to optimise training programmes and provide direction and prospects for future research.

1. Methods

Scope reviews constitute a systematic approach to knowledge synthesis, mapping the literature landscape through the retrieval, screening, and integration of existing evidence. Their core function lies in clarifying key concepts within a discipline, identifying research trends, demonstrating the diversity of existing knowledge, and charting directions for future research [13]. This study strictly adhered to the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Scrutinies of Scrutinies – Scope Review) guidelines established by Tricco et al. for standardised implementation [13].

1.1.Literature Search Strategy

Two researchers utilised PubMed, Web of Science, and China National Knowledge Infrastructure (CNKI) databases, adhering to the PICOS framework. The retrieved subject terms included: taekwondo, cognitive function, inhibitory control, executive function, sports performance, skill-related fitness, psychological skills, mental, and sport psychology. Simultaneously, a 'subject term + free term' retrieval approach was employed. Synonyms were linked using 'OR', while keywords from different categories were connected using 'AND'. The literature search period spanned from 1 January 2000 to the present.

1.2.Inclusion and exclusion criteria

The literature screening, inclusion, and exclusion criteria were established according to the PICOS principles and framework. Inclusion criteria were: 1) Study subjects were taekwondo athletes; 2) All study designs involving various types of exercise training combined with cognitive function training; 3) Exercise prescription design adhered to the standards of the American College of Sports Medicine (ACSM). 4) Primary outcome measures encompassed taekwondo performance and cognitive function; 5) Exclusion criteria comprised: 1) Non-English or non-Chinese language publications; 2) Literature unrelated to exercise prescription, taekwondo performance, or cognitive function; 3) Reviews, theses, conference proceedings, qualitative studies, and publications lacking accessible research data; 4) Articles with missing research findings or data were excluded.

1.3.Literature screening

Using NoteExpress software to process the retrieved literature for duplication reduction. Two researchers independently screened the literature, conducting an initial selection by reading titles and abstracts, followed by full-text reading of potentially eligible studies. Following selection, a third party cross-referenced and organised the literature database. Based on search results, Chinese-language articles and English-language articles were retrieved, totalling articles. Duplicate entries were removed

from the literature management software. Subsequently, two authors screened titles and abstracts, requiring consensus; where disagreement persisted after discussion, a third reviewer was consulted.

2 Results

Through systematic retrieval of electronic databases, we initially identified 397 relevant publications. After removing 131 duplicate records, the remaining 266 entries underwent title and abstract screening. Subsequently, full-text eligibility assessments were conducted on 159 publications, of which 145 were excluded for failing to meet the criteria. Ultimately, 14 studies met the inclusion criteria and were incorporated into this systematic review, as illustrated in Figure 1.

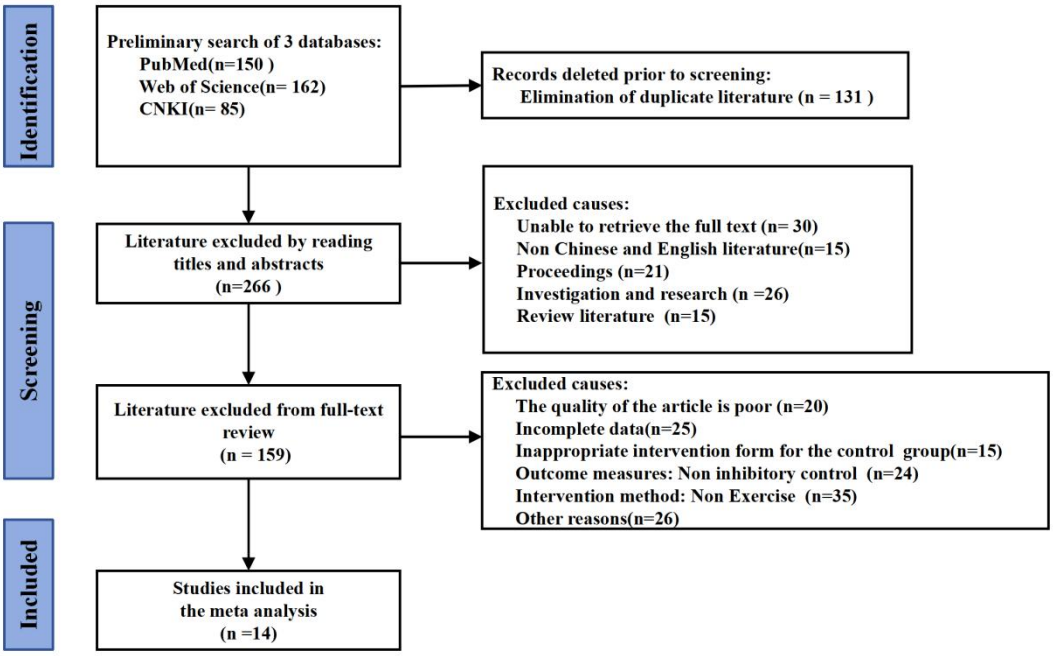

Fig. 1: Literature Retrieval and Screening Process

2.1 The Association Between Psychological Skills and Cognitive Function Performance in Taekwondo Athletes

To cultivate an outstanding athlete, psychological factors are indispensable alongside physical fitness and technical-tactical skills. Research in this domain indicates that athletes often struggle to alter ineffective patterns, experience delayed decision-making, and fail to refocus attention when distracted [14]. Consequently, even athletes possessing elite-level physical and technical capabilities may experience significantly diminished performance if their pre-competition mental state is inadequately prepared. Furthermore, existing psychological skill training encompasses diverse methodologies, including self-talk, imagery training, mindfulness practice, and pre-performance routines [15]. Particular attention has been directed towards examining changes in athletic performance following

psychological skill training interventions tailored to specific sports [12].Indeed, research has demonstrated that psychological skills training can enhance athletic performance across various specialised sports, such as football and golf. This indicates that such training plays a pivotal role in athletes' pre-competition mental preparation, potentially influencing match outcomes[16]. For taekwondo competitors executing tactics during matches, psychological capabilities prove equally indispensable alongside sound physical conditioning or competitive fitness[17]. In taekwondo contests, not only does the situation change rapidly, but competitors' psychological momentum also fluctuates throughout the match. How athletes can flexibly adapt appropriate tactics to seize winning opportunities amidst positive or negative psychological momentum represents a highly pertinent research topic [18, 19]. Beyond self-talk and imagery, psychological factors encompass the recently prominent research area of athletes' cognitive performance. High athletic ability correlates with enhanced cognitive function, particularly evident in studies of combat sports athletes [20].

2.4 The Application of Psychological Skills in Taekwondo

Previous research examining psychological factors influencing taekwondo athletes has predominantly focused on the application of mental skills training [21]. For taekwondo practitioners, maintaining an optimal psychological state necessitates integrating training with authentic competition settings and environments wherever possible. This ensures athletes remain in a state closely resembling actual competition, enabling them to rapidly enter a combat-ready state both physically and mentally during official events [19, 21]. Sotoodeh et al. (2012) studied 142 taekwondo athletes of varying skill levels (including elite and non-elite) using the Ottawa Mental Skills Assessment Tool. This tool evaluated their mental skills across three dimensions: fundamental skills, mental skills, and cognitive skills. The findings revealed that elite athletes employed competition plans and goal setting more frequently during the pre-competition phase, while also demonstrating significantly superior performance in relaxation, confidence, and self-talk compared to non-elite athletes [22]. These results indicate that mental skills training exerts a significant influence on enhancing the athletic performance of elite taekwondo practitioners. Recent research has analysed the applied benefits of mental skills training specifically for Olympic athletes [22].Psychological skills training encompassed an introduction to mental techniques, psychological assessments, performance strategies, self-talk and self-image during competition, imagery, pre-match routines, and coaching interviews. During this phase, the author collaborated with athletes and coaches to gather intelligence on opponents' specialised playing styles, developing viable counter-strategies. Athletes were also guided to reflect on past matches to identify key factors contributing to victory [23]. Moreover, the author guided athletes through dialogue

to employ self-talk for tension and anxiety relief, while establishing pre-match routines to mitigate negative emotional states (such as anxiety and nervousness). Research revealed that following psychological skills training intervention, athletes explicitly stated that the psychological skills training programme for taekwondo is one of the essential factors for achieving victory in competitions and that this psychological skills training programme has genuinely been highly beneficial for competitions[24].

This demonstrates that while psychological techniques are intangible, they significantly influence athletes' mental performance states and serve as a crucial backing for consistent execution. Finally, the researchers further indicate that regular psychological skills training by coaches can effectively help athletes cultivate positive mental states during practice and competition, assist them in overcoming anxiety, managing confidence, and performing at their peak during contests.

2.5 The Role of Inhibition Control in Taekwondo Performance

Beyond psychological skill issues, athletes' cognitive functions have also attracted considerable research attention in recent years [3, 25]. Cognitive function refers to the mental capacity by which humans process, store, and retrieve information and knowledge through the brain, encompassing abilities such as perception, memory, attention, and imagery [26]. Cognitive performance can reflect an athlete's experience or competitive level [27]. Higher-order cognitive abilities, particularly executive function, have been identified as significantly influencing athletic performance [28]. Consequently, in certain scenarios, an athlete's reaction and decision-making may prove pivotal to the outcome of a contest. In particular, inhibitory control can help prevent unnecessary errors leading to lost points. Inhibitory control is a vital ability in daily life. For instance, during emergencies, it enables us to suppress ongoing, inappropriate impulsive behaviours or thoughts to prevent undesirable consequences [29]. In taekwondo competitions, athletes frequently need to anticipate their opponent's next move. Upon observing a potential counterattack, they must instantly inhibit their planned attack or movement to avoid losing points through countering.

Executive function constitutes a higher-order cognitive capacity. Depending on scholars' definitions, it may be categorised into distinct domains, including attentional control, information processing, cognitive flexibility, and goal setting[30]. Additionally, some scholars contend that executive function relates to multiple common life skills, such as decision-making, problem-solving, working memory, and inhibitory control abilities. Within the sporting domain, researchers frequently employ various classic laboratory cognitive tasks (e.g., Go/No-go tasks, stop-signal tasks, Flanker tasks, n-back tasks) to investigate athletes' executive function performance and related topics [31, 32]. For

instance, Wang et al. (2013) employed the stop-signal task to investigate potential associations between sport type and inhibitory control, comparing athletes from open-ended versus closed-ended sports with non-athletes. Findings revealed superior inhibitory control in open-ended athletes relative to closed-ended athletes and non-athletes [33]. Researchers hypothesised that this advantage may stem from the demanding, dynamic environments and multiple uncertainties inherent in open-ended sports. Athletes in such settings must employ inhibitory control and attentional resources to achieve superior performance, thereby developing greater cognitive proficiency than closed-ended athletes or non-athletes. Furthermore, athletes in closed-system sports may develop less of this cognitive advantage due to their more stable and predictable sporting environments [33]. This demonstrates that executive function is a crucial capability influencing athletic performance, reflecting its significant potential application in sporting contexts. Consequently, assessing athletes' cognitive performance not only enables coaches and athletes to understand their mental functional states but also provides valuable reference points for future training strategies.In the context of martial arts research, Di Russo et al. (2006) employed a Go/No-go task to investigate cognitive processes potentially engaged by fencers during competitive confrontations with opponents, encompassing stimulus recognition, motor response, selection, and inhibition processes [20]. Comparing national-level fencers with a control group of ordinary students revealed that fencers exhibited shorter reaction times than the control group. Furthermore, event-related potentials (ERPs) revealed differences in neural activity across three distinct cognitive phases. Event-related potentials represent a specialised form of brain-evoked potential, reflecting neurophysiological changes in the brain during cognitive processes in response to specific stimuli. These potentials are obtained by filtering and averaging electroencephalogram (EEG) signals [34]. Common ERP components include P1, N1, P2, N2, and P3, where letters denote peak polarity and numbers indicate approximate temporal onset. Fencers exhibited a larger N1 wave related to visual processing attention compared to the control group of ordinary students. Furthermore, in the No-go condition, they demonstrated greater N2 wave amplitude and increased activation in the posterior cingulate gyrus. Finally, during the response selection phase, fencers also showed stronger prefrontal cortex activity [34]. The ability of athletes to counter opponents' feints and rapidly switch and update motor responses through anticipatory actions may be linked to attentional processes and inhibitory activity in the prefrontal cortex. Furthermore, Brevers et al. (2018) recruited members of the national fencing and taekwondo teams alongside non-athletes for a stop-signal task experiment. Results indicated that fencers and taekwondo athletes demonstrated faster reaction times and lower error rates compared to non-athletes, suggesting superior inhibitory control abilities in these athletes [35]. Thus, for martial arts athletes, inhibitory control capacity may represent a significant factor influencing competitive performance.

During taekwondo competitions, athletes must process highly complex environmental information, including spectator cheers around the arena, coaches' tactical instructions, and opponents' movements. Consequently, even when considering the sport itself, competitors require strong inhibitory control to adapt to changing match conditions [35]. Research has confirmed a correlation between taekwondo training experience and the development of inhibitory control. Research indicates that in Go/Nogo experiments, taekwondo experts exhibit significantly shorter reaction times to Go stimuli than novices, demonstrating superior responsiveness [9]. Experimental studies employing varying temporal intervals confirmed that a 900-millisecond gap between cue and target precisely coincides with the ultra-long-term phase, during which participants achieve peak reaction speed [10]. Lakes et al. (2013) recruited 60 non-taekwondo-trained students from two classes and assigned them to experimental and control groups by class. The experimental group replaced three of their weekly physical education sessions with taekwondo training, while the control group maintained their original five-session schedule. Findings revealed significant improvements in the experimental group's executive functions by the end of the term, with particularly marked gains in inhibitory control performance [36]. Similarly, Kim (2015) recruited 14 university students, evenly dividing them into experimental and control groups. The experimental group underwent an 8-week taekwondo training intervention, after which their performance on the Stroop Colour and Word Test (SCWT) was assessed. The findings revealed that the experimental group achieved significantly higher scores on the Stroop test compared to their pre-test performance, with a significant difference also observed relative to the control group. Conversely, the control group showed no significant difference between pre- and post-tests. These results indicate that taekwondo training can effectively enhance inhibitory control abilities [37].Additionally, Cho et al. (2017) extended the experiment to primary school children, primarily recruiting 35 pupils aged 10 to 12. Seventeen pupils were randomly assigned to the experimental group, while 18 were placed in the control group. The study observed changes in their SCWT scores following 16 weeks of taekwondo training. Results revealed that following the taekwondo intervention, the experimental group demonstrated a significant increase in SCWT scores compared to pre-test levels. Conversely, the control group showed no significant difference between pre- and post-test scores. These findings corroborate the research team's earlier conclusion, suggesting a causal association between taekwondo training and enhanced inhibitory control abilities[38].

3 Discussion

Based on the literature review in this study, becoming an outstanding taekwondo athlete requires not only physical fitness elements such as good cardiorespiratory capacity, lower-body strength, agility, and motor coordination to support the execution of techniques and tactics, but also cognitive functions. These are indispensable, particularly in the fast-paced and intense confrontations of taekwondo, where

inhibitory control plays a crucial regulatory role. However, whilst current research findings demonstrate promise, empirical studies and practical applications of cognitive function within taekwondo training require further evidence-based support. We encourage practitioners to apply principles of cognitive science to develop physical-cognitive training models tailored to the specific skills of taekwondo.For instance, Taekwondo experts demonstrated markedly faster reaction times in Go tasks than novices, and significantly faster response speeds in non-valid cue tasks compared to valid cue tasks. Both experts and novices exhibited a return inhibition effect, with Taekwondo experts showing greater return inhibition, indicating superior attention-shifting capabilities between focus and inhibition [14]. Furthermore, activation of the Nogo-N2 component in the frontal region is often regarded as an effective indicator of inhibitory capacity, correlating with activation in brain areas such as the dorsolateral prefrontal cortex associated with inhibition. A prominent N2 component evoked in the frontal lobe signifies superior inhibitory control [3]. Consequently, the development of inhibitory control may be closely linked to taekwondo training. Future research is recommended to establish associations between competitors' match states and inhibitory control performance, thereby identifying the underlying cognitive mechanisms and contexts influencing taekwondo decision-making. Furthermore, past studies have primarily employed laboratory-based tests to explore the relationship between athletes' brain activity and performance. Researchers have also indicated that while laboratories allow rigorous control over most potential confounding factors and demonstrate good internal validity, ecological validity issues arise when applying findings to real-world settings. To bridge the gap between laboratory findings and real-world application, future researchers may leverage technological advancements such as LED installations and virtual reality devices to bridge the gap between laboratory and actual competition environments [39], thereby developing methodologies that balance internal and ecological validity. Finally, should cognitive functions prove significant for taekwondo performance, future training programmes may consider integrating cognitive training concepts into routine practice. This would assist athletes in making optimal reaction decisions within the rapidly changing dynamics of competition.

4 limitations

This study has several limitations. Firstly, the number of included studies is limited, and most have small sample sizes, which may affect the generalisability of the findings. Secondly, existing research predominantly focuses on laboratory settings, exhibiting limited ecological validity and thus failing to fully reflect the role of inhibitory control in real-match scenarios. Furthermore, variations exist across studies in terms of cognitive tasks, training intervention protocols, and assessment tools, posing challenges for comparing and synthesising results. Future research should expand sample sizes, standardise assessment criteria, and strengthen investigations into cognitive functions within competitive settings to enhance the reliability and practical applicability of conclusions.

5 Conclusion

Inhibitory control, as a core component of executive function, plays a significant role in the competitive performance of taekwondo athletes. This study, through a systematic review, found that taekwondo training not only enhances athletes' physical fitness and technical-tactical proficiency but also markedly improves their inhibitory control abilities. This, in turn, optimises decision-making speed and reaction accuracy during competitions. Future training should systematically incorporate cognitive

function training, integrating modern technologies such as virtual reality and neurofeedback to develop more ecologically valid assessment and intervention methods. This approach will comprehensively enhance both the competitive performance and psychological resilience of taekwondo athletes.

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