Effects of core strength training on the technical skill performance of striking combat sport players: a systematic review

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ABSTRACT

Research purpose. This review investigated the effects of core strength training on the competitive performance of players participating in striking combat sports. By analyzing karate, taekwondo, boxing, Chinese martial arts, and Muay Thai, the study examined the effects of core strength training on the number of kicks, striking force, and impact speed of players. The aim of this study was to provide a theoretical basis for training methods in striking combat sports and to explore the role of core strength in improving players' actual competitive performance.
Methods. Data for this study were reported using the Preferred Reporting Project for Systematic Review and Meta-Analysis (PRISMA) guidelines. On November 1, 2023, a full search was conducted on SCOPUS, PubMed, Web of Science, EBSCO, CNKI (only core academic journals were included in the search, specifically those listed in recognized Chinese journal evaluation systems such as the Beijing University Core Journals or CSSCI, thereby excluding non-academic or low-tier publications.) and Google Scholar (*via* EBSCOhost) searching engine. PICOS determined the inclusion criteria: (1) Combat sports player; (2) core strength training; (3) the enhancement intervention was compared with the control group or other exercise groups, and a single-group test was conducted; (4) test at least one technical skill performance; (5) non-randomised research trials and randomised controlled designs. Only eight of the 826 studies met all inclusion criteria and were included in the systematic review.
Results. In karate, wheel kick scores were significantly increased after core strength training; in taekwondo training groups, the number of kicks in 30 seconds was increased considerably; in boxing, 10-second and 20-second sandbag strikes and performance in 1 minute were significantly increased, and backhand punch strikes were enhanced; in martial arts, the striking power and relative striking power of straight punches and whip kicks were increased considerably; and in Muay Thai, jabs were made possible by both static and dynamic training; the knee strike and other manoeuvres had significant increases in striking power and impact speed. Overall, core strength training positively affected the frequency of kicks, striking power, and impact speed in all striking combat sports.

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Additional Information and Declarations can be found on page 14

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Conclusion. The number of kicks, striking force, and impact speed in karate, taekwondo, boxing, Chinese martial arts, and Muay Thai have all improved, with particularly notable improvements in roundhouse kicks, straight punches, and whip kicks. core strength training has enhanced players' strength and physical stability, improving movement control and explosive power. Therefore, incorporating core strength training into striking combat sports training can comprehensively improve players' practical performance and physical fitness levels.

Subjects Sports Injury
Keywords Core strength, Striking combat sports, Training, Players' performance

INTRODUCTION

Combat sports are athletic activities that involve physical contact and competition between two individuals or teams, typically to defeat the opponent using techniques, strength, and strategy. These sports include boxing, wrestling, judo, taekwondo, mixed martial arts, and others (*Guttmann, 2004*). Combat sports are a form of physical exercise, competition, and skill demonstration platform. Combat sports rely on various technical skills for effective offence and defence. players employ striking techniques like punches (jab, cross, hook, uppercut), kicks (roundhouse, front, side, back), elbows, and knees. Grappling involves throws (hip, shoulder, leg sweep), takedowns (single-leg, double-leg), and submissions (joint locks, chokes) for ground control. Defensively, they use blocking (parrying, blocking punches/kicks) and evasion (bobbing, weaving, slipping). Footwork (angles, distance, circling, lateral movement) is crucial for positioning and creating opportunities. These skills are fundamental in combat sports, shaping competition's dynamic and strategic nature (*Del Vecchio, Hirata & Franchini, 2011*).

The basic techniques of combat sports require core strength to stabilise the upper body and transfer power from the lower to the upper limbs. In boxing, for example, combat sport players use the rotation and stabilisation of the core muscles to transfer power from the lower limbs to the fists to maximise the impact of the blow (*Lenetsky, Harris & Brughelli, 2013*). Second, wrestling, jiu-jitsu, and other throwing techniques heavily depend on core strength. These techniques often involve pulling, twisting, and rotating movements, necessitating players to maintain core stability in various directions (*Iwai et al., 2008*). Players must pull their opponents towards them or flip them over through their core when executing drop throws. The core's strength and endurance can effectively support these manoeuvres, allowing for a more efficient power transfer and reducing lumbar spine stress. In summary, core strength is crucial in combat sports, which not only helps increase power output and improve movement control, enhances endurance and stability, and reduces the risk of injury. Therefore, targeting the core muscles in combat training is critical to enhancing technical performance (*Franchini et al., 2011*).

The core refers to the abdominal muscles in the front, the paracinatus and gluteus muscles in the back, the diaphragm above, the oblique muscles in the side, and the pelvic muscles below (*Akuthota & Nadler, 2004*; *Hibbs et al., 2008*). These muscles are crucial in stabilising the body during movements and transferring power between the upper and lower body (*McGill, 2010*). A solid core power can be efficiently transferred from the lower limbs to the upper limbs, essential for optimal movement and function (*Bompa, 1999*; *McGill, 2009*). Improved core strength enhances balance, stability, and overall body control, leading to more efficient technique execution and reduced risk of injury in combat sports (*Escamilla et al., 2002*; *Huxel Bliven & Anderson, 2013*). Previous studies have shown that short-term stability ball core stability training, administered twice weekly for six weeks, can effectively enhance trunk stability (*Sekendiz, Cug & Korkusuz, 2010*).

Additionally, the enhancement of athletic performance through core strength training can be systematically explained from two perspectives: motor control mechanisms and biomechanical functions. In terms of motor control, *Hodges & Richardson (1997)* proposed that core muscle groups not only provide support during movement but also maintain dynamic postural stability through active neural regulation, thereby improving movement coordination and precision. From a biomechanical perspective, *Kibler, Press & Sciascia (2006)* pointed out that insufficient core stability can lead to disruptions in the kinetic chain, resulting in limited force output, reduced movement efficiency, and even sports injuries. The article further emphasizes that core stability not only affects the efficiency of force generation and transmission during movement but also determines the integrity of coordinated movements among different body parts during movement. *Behm & Anderson (2006)* explored the effects of core strength training in unstable environments (*e.g.*, using balance balls or unstable surfaces). The study found that while such training temporarily reduces the absolute value of force output, it significantly enhances the neural activation levels of core muscle groups and multi-muscle coordination. Therefore, core strength training achieves active neural control through early activation of core muscle groups and improves biomechanical efficiency by enhancing the integration of the kinetic chain, thereby providing dual support for the execution of technical movements.

Although numerous studies have highlighted the importance of core strength in stabilising the body and transferring power, their focus has been chiefly on general athletic performance rather than the nuances of striking combat sports. Despite these findings, most existing studies on core strength training have focused on general fitness or traditional sports, with limited attention given to striking combat sports such as boxing, karate, taekwondo, Muay Thai, and Chinese martial arts. These sports involve rapid, forceful movements such as punches and kicks, placing unique demands on the core for power transmission and dynamic control. Furthermore, there remains a lack of clarity regarding the relative effectiveness of static *versus* dynamic core strength training in enhancing performance across different striking disciplines. To address these gaps, this review systematically evaluates current evidence on core strength training in striking combat sports. It aims to determine how various training approaches impact specific performance metrics (*e.g.*, strike power, frequency, and speed), offering practical insights for coaches, players, and practitioners seeking to optimize physical preparation in these sports.

METHODS

Protocol and registration

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review protocol was prospectively registered on the INPLASY platform (Registration No. INPLASY2023120102 (https://inplasy.com/); DOI: 10.37766/inplasy2023.12.0102). Portions of this text were previously published as part of a preprint (*Zhang & Soh, 2023*).

Search strategy

By November 2023, a comprehensive literature search was conducted using academic databases, including Scopus, PubMed, Web of Science, EBSCO, and CNKI (limited to core academic journals). Additionally, Google Scholar was accessed *via* EBSCOhost to ensure the inclusion of relevant studies. We performed strategic search queries by title and abstract in each database. The main keywords of relevant studies collected are: ("Core Strength Training" OR "Core-muscle Training" OR "Core training" OR" Core-stability Exercise" OR "Core Exercise") AND ("Technical skill" OR "Skill" OR "Technique" OR "Performance") AND ("Combat sport" OR "Mixed martial arts" OR "MMA" OR "Boxing" OR "Kickboxing" OR "Judo" OR "Judoka" OR "Karate" OR "Taekwondo" OR "Wrestling" OR "Sanda" OR "Muay Thai" OR "Sambo" OR "Savate"). Due to heterogeneity in outcome measures and reporting formats, a quantitative meta-analysis was not feasible. The search strategy in the Methods section was conducted by Shuai Zhang and Shengyao Luo. In cases where disagreements arose regarding study selection or data inclusion, discussions were held between the two authors to reach a consensus. If a resolution could not be achieved, the corresponding author of this manuscript served as the referee and made the final decision.

Eligibility criteria

The PICOS was used for literature retrieval. The acronym PICOS stands for the following concepts: (1) population, (2) intervention, (3) comparison, (4) outcome, and (5) study design. The study used each PICOS as an inclusion criterion for retrieving publications. Studies must meet each of the following inclusion requirements (Fig. 1). Portions of this text were previously published as part of a preprint (*Zhang & Soh, 2023*).

(1) The study population must include healthy players, regardless of gender or age.
(2) At least four weeks of core strength training on stable or unstable surfaces.
(3) The comparison in the study can be a single-group trial or a multi-group trial.
(4) An outcome addressing the impact of at least one core strength intervention on combat sports players.
(5) The article must be an experimental study, including a single-group or randomised controlled trial.

Study selection

The articles met the pre-set inclusion criteria and were independently screened by two authors. After removing duplicates, one author first conducted a preliminary review of the

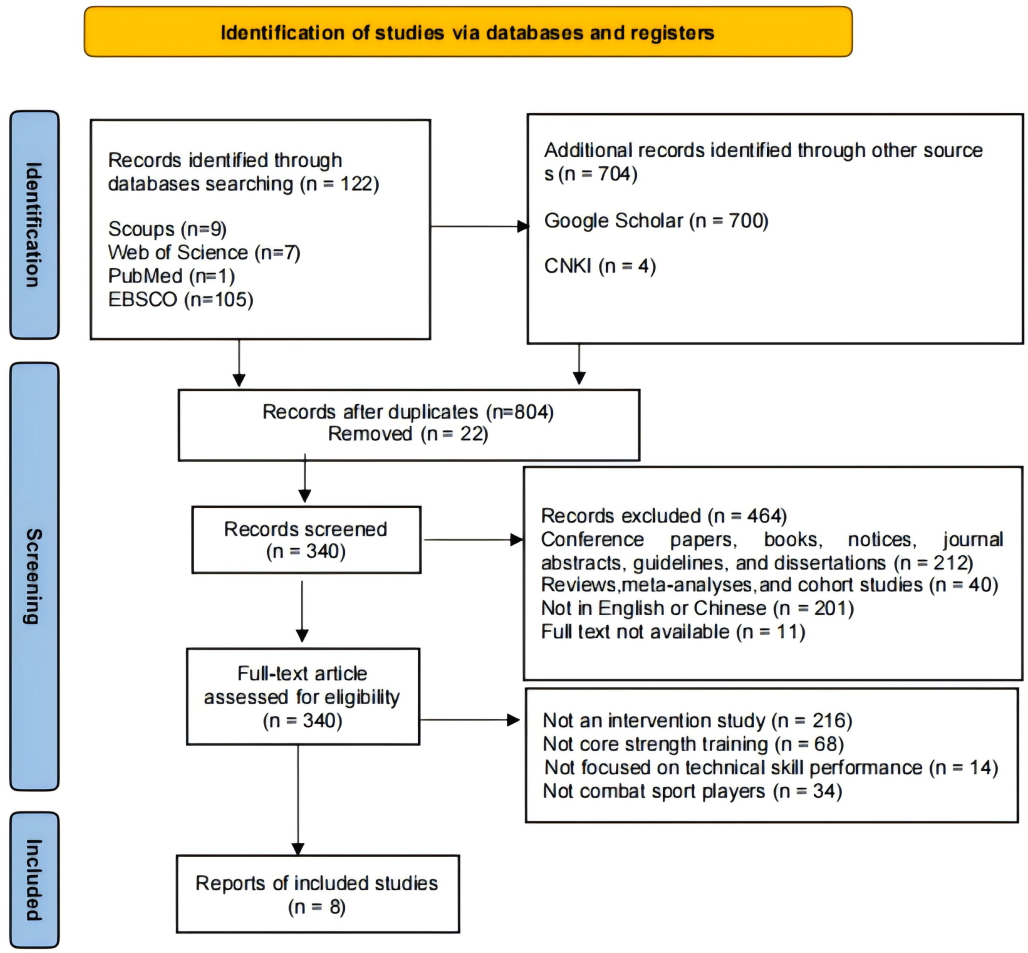

Figure 1 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources. For CNKI, only academic documents in SCI, EI, PKU, CSSCI and CSCD were retrieved.

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titles and abstracts to determine which documents might meet the inclusion criteria. If the two authors disagreed on whether a document should be included, a third author reviewed the full text and made the final decision.

Data extraction

Two researchers extracted information from each study using a Microsoft Excel spreadsheet (Microsoft Corporation, Redmond, WA, United States), while a third researcher cross-checked the data for accuracy. The data collected included: (1) the name of the author and the year of publication; (2) demographic characteristics such as the number of participants, their gender, age, and type; (3) details about the intervention, including its type, measurement index, frequency, and duration; (4) research findings.

This study used the Cochrane Collaboration's Risk of Bias Tool (RoB) to assess the quality of the included randomised controlled trials. Please refer to Figs. 2 and 3 for details. Based on the risk-of-bias assessment using the Cochrane RoB 2.0 tool, the overall quality

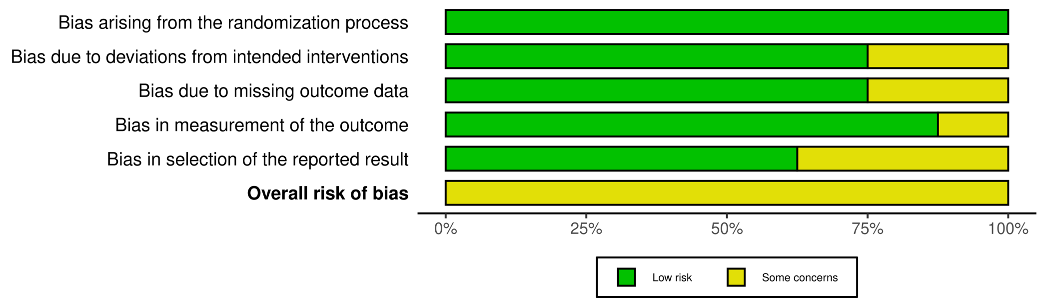

Figure 2 Risk of bias assessment for the eight included studies across five domains (D1–D5) and overall judgment. Potential bias in each study using the Cochrane Risk of Bias 2.0 framework, indicating a moderate overall risk of bias.

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of the included studies was judged to present some concerns. Specifically, the domain of bias arising from the randomization process was rated as low risk across all randomized controlled trials (RCTs), indicating sound randomization procedures. In the domain of bias due to deviations from intended interventions, 75% of the studies were rated as low risk, while the remaining 25% had some concerns. A similar pattern was observed for bias due to missing outcome data, where 75% were low risk and 25% some concerns. Regarding bias in measurement of the outcome, 90% of the studies were rated as low risk, suggesting appropriate outcome assessment methods were used. However, in the domain of bias in selection of the reported result, only 60% of the studies were assessed as low risk, indicating potential issues with selective outcome reporting in some studies. All were pre-post intervention studies without explicit randomization or control group allocation. Therefore, the results should be interpreted with caution.

RESULTS

Study selection

The literature screening method is as shown in PRISMA. A total of 826 documents were identified through a search of core academic journals in the CNKI database. After the initial screening, duplicate records were removed using EndNote software, resulting in 804 documents. In the second round of screening, 212 records not published in academic journals (including conference papers, book chapters, notices, abstracts, dissertations, and other non-peer-reviewed materials) were excluded. Additionally, 40 literature reviews and cohort studies, 11 articles without full-text availability, and 201 articles not written in English or Chinese were removed, leaving 340 articles for full-text screening. In the third round, these 340 full-text articles were assessed for eligibility. The results showed that 216 articles were not experimental intervention studies, 68 did not focus on core strength training, 14 were unrelated to technical skill performance, and 34 did not involve combat sports players. Ultimately, eight articles met the inclusion criteria.

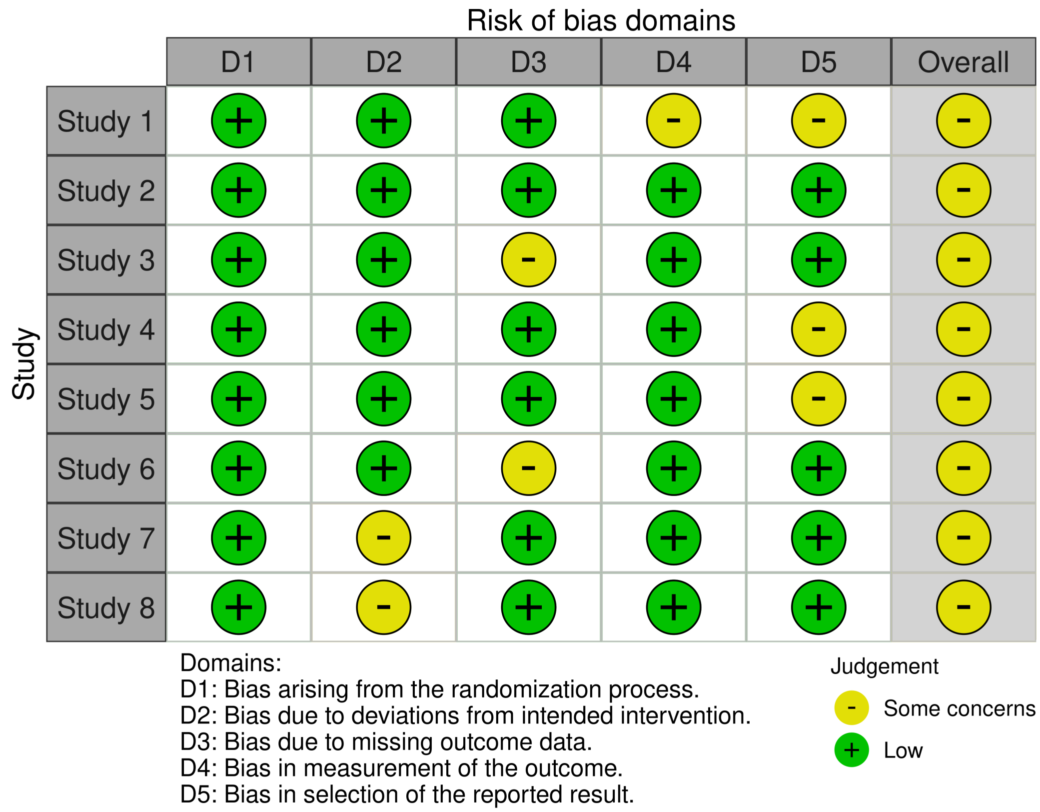

Figure 3 Overall risk of bias summary across five domains for the included studies. Aggregated proportion of studies judged as "low risk," "some concerns," or "high risk" within each of the five domains of the Cochrane Risk of Bias 2.0 tool: (1) bias arising from the randomization process, (2) bias due to deviations from intended interventions, (3) bias due to missing outcome data, (4) bias in measurement of the outcome, and (5) bias in selection of the reported result. Most studies were judged to have some concerns and low risks across multiple domains, resulting in an overall risk of bias classification of "some concerns."

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Participant characteristics

Table 1 summarises the characteristics of the eight studies met the inclusion criteria, as shown below.

(1) Classification of fighting events. Of these eight articles, two are about boxers at the professional level (*Zhang et al., 2023*; *Brown et al., 2021*). Two articles are about professional karate players (*Kamal, 2015*); Amateur karate players (*Kabadayıet al., 2022*); The other four are about martial arts players (*Haifan, Haixiang & Qi, 2023*); Taekwondo players (*Xiao & He, 2023*); Sanda players (*Han & Zhang, 2013*); Muay Thai players (*Lee & McGill, 2017*).

(2) Number, gender, and age. The total number of participants was 165, comprising 54 males and 51 females; the sex of the remaining 60 participants was not specified in the original publications (*Haifan, Haixiang & Qi, 2023*; *Xiao & He, 2023*). The studies noted that five of the studies involved participants over 18 years old, and three studies involved participants under age 14.

Table 1 Summary of the eight included studies, detailing the characteristics of the study population, the interventions applied, comparators used, and reported outcomes (PICO).

Study	Design	Population characteristics					Intervention	Comparator	Outcome
		N	Sex	Age	Participants	Player Exp/level			
Kamal (2015)	Pre-post test	20	F	12.54	Youth karate players	Pro	Freq:10-weeks	EG:core strength training CG:traditional training	Core Muscle Strength & Stability Test (CST) ↑, Static strength test (LS) (BS)↑, Standing Long Jump Test (SLJ)↑, Seated Medicine Ball Throw (SMBT)↑, Dynamic balance test (DBT) ↓Performance specifications ↑
Kabadayıet al. (2022)	Pre-post test	29	M&F	EG: 12.75 ± 0.77 CG: 13.00 ± 0.91	Youth karate practitioners	Amateur	Freq:8-weeks/5 time	CG:sport-specific (karate)programme(SSp) EG:karate practice/core strength training	FET↑, BET↑, Right LMT ↑, Left LMT↑, Flexibility ↑, Pro-agility ↑, CMJ↑, BMS ↑, Horizontal jump ↑, 10 m ↑, 20 m ↑, Right kick (rep) ↑, Left kick (rep) ↑
Haifan, Haixiang & Qi (2023)	Pre-post test	20	NR	EG: 18.96 ± 1.59 CG: 18.44 ± 1.61	Martial arts players	Pro	\	EG: core strength training associated with traditional physical training CG: traditional physical training	Straight punch ↑, hitting force of straight fist↑, whip leg hitting force ↑, whiplash leg relative hitting force↑
Brown et al. (2021)	Pre-post test	20	M	24.20 ± 2.90	Boxers	Pro	Freq:6-weeks	EG: core stabilisation CG: traditional training	Rear hand punching power↑
Zhang et al. (2023)	Pre-post test	10	M	19.61 ± 3.12	Boxers	Pro	Freq:3-months	EG: core resistance training	Boxers'1min medicine ball ↑, 1 min skipping rope ↑, 30 s left rotation and 30 s right ↑, rotation↑, 10-second sandbag ↑, 20-second start-up target ↑, 1-minute medicine ball ↑, double rocking skipping rope 1 min↑, 30-second left turn↑, 30-second right turn↑, 400 m running ↔, 1 point sandbag ↔, Interval running 2 min×4 ↔
Han & Zhang (2013)	Pre-post test	14	F	18.14 ± 2.76	Sanda players	Pro	Freq:24-week/2 time	EG:core strength training CG:strength training	Number of punches in about 30 s↑ Number of kicks in 30 s ↑ 20 m start time↔
Xiao & He (2023)	Pre-post test	40	NR	12.25 ± 0.52	Taekwondo players	\	Freq:3-months	CG: club's regular exercise program EG: stabilization exercise	CG:30 s median cross kick↔ EG:30 s median cross kick↑
Lee & McGill (2017)	Pre-post test	12	M	24.20 ± 2.90	Muay Thai players	Amateur & pro	Freq:6-weeks	EG: isometric core exercise CG1: dynamic core exercise CG2: routine training	CG1: Impact force↑, Strike velocity↑, muscular activation↑ CG2: Impact force↑, Strike velocity↑, muscular activation↑

Notes.
EG, Experimental group; CG, control group; ↑, significant improvement; ↔, no significant difference; ET, flexor endurance test; BET, back extensor test; LMT, lateral musculature test; Rep, repetitions; Sec, seconds; Pro, Profession; F, Female; M, Male.

Intervention characteristics

Table 1 shows several essential components of the intervention characteristics of this study, including intervention type, duration, and frequency. Core strength training is the primary intervention modality, alternatively referred to as core stability training (*Brown et* al., 2021; Xiao & He, 2023) and core resistance training (Zhang et al., 2023). One paper is a comparative study of three groups (Lee & McGill, 2017). In addition to one paper (Zhang et al., 2023), which is controlled before and after the experiment, The remaining six papers all compared the difference in skill performance between core and regular training. In terms of duration, the studies ranged from 4 weeks to 3 months. In these studies, except for one study that did not specify the training period (Haifan, Haixiang & Qi, 2023), the intervention period was defined in the other studies, and the intervention period was three months in two studies (Zhang et al., 2023; Xiao & He, 2023). Two studies had an intervention period of 6 weeks (Lee & McGill, 2017; Brown et al., 2021), and the remaining studies had intervention periods lasting eight weeks (Kabadayıet al., 2022) and 10 weeks (Kamal, 2015). The study lasted 15 weeks (Han & Zhang, 2013). In terms of frequency, only two studies reported training frequency. Three times a week (Han & Zhang, 2013), twice a week (Kabadayıet al., 2022), and six other studies did not specify a frequency.

OUTCOME

Effect of core strength training on karate

Two studies on the sport of karate, one studied the performance of 20 young female karate players in combat events (Kamal, 2015) after testing the wheel kick score (6.50 $\pm$ 0.05 points *vs.* 5.59 $\pm$ 0.06 points, $P < 0.05$). Kabadayıet al. (2022) demonstrated that eight weeks of core strength training can improve core endurance and karate kicking performance in youth karate practitioners; however, the training did not significantly improve other physical performance indicators in Korean martial arts (KR) practitioners.

Effect of core strength training on Taekwondo

Xiao & He (2023) conducted a 3-month stabilisation training and routine exercise training intervention on 40 Taekwondo players. The average number of kicks within 30 s was significantly improved in the experimental group compared to the control group during the stability period (39.45 $\pm$ 1.66 *vs* 40.85 $\pm$ 1.93; $P < 0.05$). This indicates that core muscle strength training can enhance core muscle strength in taekwondo players.

Effect of core strength training on boxing

In Zhang et al.'s (2023) study, after three months of core strength training, players' physical performance test results significantly improved ($P < 0.01$). Although scores in the 400-meter run, sandbag training, and interval running were higher than before training, the differences were not significant ($P > 0.05$). Core strength training can enhance the physical performance and boxing skills of boxers. Another study (Brown et al., 2021) conducted a six-week experimental intervention on 20 boxers, finding that the impact force of the rear hand punch significantly increased in the experimental group (17,781 $\pm$ 1,490 *vs.* 22,014 $\pm$ 1,336, $P < 0.001$; $G = 4.41$).

Effect of core strength training on Chinese martial arts

Haifan, Haixiang & Qi (2023) found that after intervening with 20 martial arts players, at the end of the experiment, significant differences were observed between the groups, with the most significant differences in straight punch striking force and relative striking force. Additionally, whip kick striking force and relative striking force also showed significant differences (1,713.01 ± 176.523 *vs.* 2,120.55 ± 254.505; 25.75 ± 2.603 *vs.* 31.89 ± 3.722; $p < 0.001$) and whip kick striking force and relative striking force (2,502.59 ± 395.095 *vs.* 3125.84 ± 398.832; 37.64 ± 5.868 *vs.* 47.00 ± 6.057; $p < 0.005$). Another experimental study on core strength training for female kickboxing players (*Han & Zhang, 2013*) found that the experimental group had a higher number of punches per 30 s (125.57 ± 10.37 *vs.* 134.86 ± 8.86; $p < 0.01$) and the number of leg swings within 30 s (61.14 ± 1.90 *vs.* 65.57 ± 2.37; $p < 0.01$). The conclusions indicate that core strength can enhance the rapid strength, strength endurance, and stability of kickboxing players, but its effect on improving maximum strength is not significant.

Effect of core strength training on Muay Thai

Long-term core strength training, dynamic core strength training, and routine training interventions using different interventions for 12 players (*Lee & McGill, 2017*). The impact force of Jab action increased by 17.9% after static training (2,539.3 ± 89.1N *vs* 3,093.7 ± 69.4N; $p < 0.01$). After dynamic training, it increased by 18.3% (2,614.7 ± 493.1 *vs* 3,199.6 ± 437.9; $P = 0.01$). The impact force of the Knee movement increased by 13.1% after static training (8,242 ± 132.3N *vs* 9,482 ± 152.8N; $P = 0.03$), the impact force of the Cross movement increased by 7.1% after dynamic training, and the impact force of the Cross movement increased by 27% after static training. In the static training group, the peak impact velocity in the Cross test increased by 23.9% (6.7 ± 0.7 *vs* 8.8 ± 0.9 m · s−1; $P = 0.01$). The second shock of the Combo test increased by 5.2% (7.1 ± 0.5 *vs* 9.0 ± 1.0 m · s−1; $P = 0.03$). In the dynamic training group, the peak impact velocity of the Jab test increased by 22.4% (4.5 ± 4 *vs* 5.8 ± 6 m · s−1; $P = 0.006$). Cross tests increased by 45.5% (6.6 ± 0.9 *vs* 12.1 ± 1.3 m · s−1; $P < 0.001$). The combo test increased by 13.2% (7.6 ± 0.8 *vs* 10.4 ± 1.0 m · s−1; $P = 0.01$). The Knee test increased by 29.1% (7.8 ± 0.6 *vs* 11.0 ± 1.0 m · s−1; $P = 0.04$). Comparison between training groups: in the cross-trial, static training increased impact velocity by 2.1 ± 0.3 m/s, while the control group only increased it by 0.3 ± 0.1 m/s. Static training also increased the first and second shock velocities of the Combo trial by 0.3 ± 0.04 m/s and 1.9 ± 0.1 m/s, respectively, while reducing them by 0.6 ± 0.1 m/s and 0.5 ± 0.05 m/s in the control group. Static training also increased the impact velocity in the Knee test by 1.2 ± 0.1 m/s, compared to 0.4 ± 0.05 m/s in the control group.

DISCUSSION

In karate, both *Kamal (2015)* and *Kabadayıet al. (2022)* studies have noted the significant effect of core strength training in enhancing kicking performance. *Kamal (2015)* found that 20 female karate players who underwent core strength training showed substantial improvements in their round kick scores, suggesting that strengthening the core muscle groups helps to improve the stability and accuracy of kicking. This was further confirmed by a study by *Kabadayıet al. (2022)* where 8 weeks of core strength training significantly improved the players' performance on the kicking test, reflecting the role of core strength in improving the efficiency of lower limb power transmission and enhancing body balance stability. In taekwondo, *Xiao & He (2023)* found a significant increase in the number of kicks in the experimental group through a 3-month intervention of stability training and conventional training, especially in improving the number of kicks within 30 s. This suggests that stability training combined with core strengthening can effectively improve players' explosive power and body control, especially in high-frequency kicking manoeuvres, and a stable core helps to complete more efficient manoeuvres quickly. Studies have pointed out the role of core strength training in enhancing power output and speed in boxing. *Zhang et al. (2023)* measured multiple performance indicators of boxers; although boxing frequency and strength improved, there were no significant differences in aerobic endurance (400-meter run test) after core strength training intervention. This suggests that core strength is crucial for enabling boxers to rapidly and accurately generate force, thereby enhancing striking power and stability. *Brown et al. (2021)* conducted a similar study and found that six weeks of core strength training significantly increased the power of the rear hand punch. This indicates that core strength can enhance the force transmission efficiency of boxers, thereby making their punches more explosive and impactful.

After core strength training, the striking power of straight punches and whip kicks of Chinese martial arts players was significantly enhanced, improving not only the absolute striking power but also the relative striking power (*Haifan, Haixiang & Qi, 2023*). This suggests that core strength substantially affects the power enhancement of different striking movements in martial arts. Female Sanda players significantly increased strikes in 30 s, especially leg movements (*Han & Zhang, 2013*). Enhancing core strength can provide stable support during the more frequent striking manoeuvres in sporadic sparring matches, strengthening the power and frequency of strikes. The value of core strength training in combat sports is further supported. Through different forms of core strength training, including static and dynamic core strength training, Muay Thai players experienced significant increases in impact and speed in the jab, knee, and cross manoeuvres. Dynamic training, in particular, significantly affected the growth in striking speed, which was particularly prominent in the jab and cross movements (*Lee & McGill, 2017*). Improving core strength can help Muay Thai players enhance the explosive power and precision of strikes and improve the consistency and efficiency of movements in competition.

Core strength training enhances athletic performance across these sports but requires sport-specific adaptations to address unique movement demands. For example, Taekwondo and karate may benefit most from stabilisation and rotational exercises, whereas boxing may benefit from core exercises that support upper-body movement efficiency. Meanwhile, the explosive demands in Chinese martial arts and Muay Thai suggest that dynamic and static core strength training are beneficial for maintaining power and control in multi-directional strikes.

These findings align with additional literature emphasising core strength's impact on sports performance. *Behm et al. (2010)* found that core strength improves athletic power, endurance, and neuromuscular coordination, essential in sports requiring rapid shifts between offensive and defensive moves. Furthermore, *Hibbs et al. (2008)* argued that core stability is fundamental for energy transfer in upper and lower body movements, making it particularly relevant for combat sports that rely on whole-body coordination.

The implications of these findings are valuable for developing effective training programs that incorporate core strength exercises tailored to each sport. Training protocols might include stabilisation exercises for sports needing high-speed repetitive movements (*e.g.*, Taekwondo) or rotational strength exercises for sports like boxing that require powerful punch generation. Future research should examine the long-term effects of these tailored training programs on combat sports performance, exploring how variables such as core strength training duration, intensity, and specific exercises affect athlete performance across competitive levels.

LIMITATIONS

This review acknowledges several limitations related to the design and implementation of the included studies examining the effects of core strength training on performance in various striking combat sports. First, the sample sizes across studies were generally small, with most involving between 12 and 40 participants. Moreover, many studies focused on specific gender and age groups. For instance, the karate-related study exclusively examined 20 young female players, which may introduce bias when attempting to generalize findings to broader populations. In addition, individual differences, including factors such as body size, muscle strength, and training experience, may lead to differences in core strength training effects across populations, thus limiting the generalisability of the findings.

Second, there needs to be more consistency in core strength training interventions' duration and training content. The length of intervention in different studies ranged from 6 weeks to 3 months, and the training modalities covered both static and dynamic core strength training, which made it difficult to draw consistent conclusions when analysing the effects of different interventions on combat sports. In particular, the difference between the effects of static and dynamic core strength training was significant in the Muay Thai. However, the comparative analysis of the two methods needed to be revised, which may limit the study's significance in guiding the optimisation of training protocols. In addition, the specific components and intensity of core strength training were not described in detail in the study, making it difficult for other researchers to accurately replicate the training protocols and assess the effects of specific training modalities on the actual performance of the striking combat sport players.

The metrics used to test athletic performance varied across studies, and some metrics needed more systematicity. For example, boxing and Chinese martial arts studies have primarily used striking force and speed as assessment metrics, whereas karate and taekwondo have favoured kick counts and frequency. This inconsistency in testing metrics increases the difficulty of cross-sport comparisons and limits the possibility of generalising the effects of core strength training across combat sports. At the same time, some testing methods' objectivity and accuracy may be compromised. For example, the 30-second and 1-minute strike count tests are somewhat subjective regarding counting accuracy, and the lack of standardised measuring instruments may affect the reliability of the results.

To enhance the value of core strength training in combat sports, it is recommended that future research should be improved in the following aspects: First, the sample size should be enlarged to enhance the representativeness and generalisability of the findings, especially to validate them among players of different genders and age groups. Secondly, it is recommended that the duration of intervention and training content be standardised or that the effects of various training modalities be explicitly compared to assess the optimal protocol for core strength training more scientifically. In addition, developing standardised test metrics would facilitate cross-sport comparisons, leading to a more comprehensive understanding of the role of core strength training in different striking combat sports.

CONCLUSION

Core strength training has demonstrated significant positive effects in various striking combat sports, enhancing players' offensive output, speed, and endurance while improving their overall athletic performance. Core strength training has significantly enhanced the effectiveness of kicks or strikes in multiple combat sports, including karate, taekwondo, boxing, Chinese martial arts, and Muay Thai. Different striking combat sports show varying degrees of improvement. For example, karate players have seen significant improvements in kicking performance through core strength training. In taekwondo, players have also seen significant improvements in kicking frequency. For boxers, core strength training has improved striking power and frequency during boxing, particularly during high-intensity strikes in short bursts. In Chinese martial arts, core strength training has improved the power and speed of techniques such as straight punches and roundhouse kicks. Muay Thai players, through static and dynamic core strength training, have demonstrated significant improvements in striking power and impact speed in techniques such as knee strikes, jabs, and combination moves. These findings indicate that core strength training can enhance players' physical performance, particularly in terms of strength and speed, providing strong support for their performance in competitions.

The reason core strength training produces significant effects in these combat sports may be closely related to its ability to enhance players' core stability, efficiency of force transmission, and whole-body coordination. The core region is a hub for power transfer between the upper and lower extremities, directly affecting the power and speed of attacking movements. However, this study did not address the issue of fatigue accumulation. Therefore, further research is needed to verify the effects of core strength training on reducing the risk of sports injuries and fatigue in players.

Despite this, some studies have shown that core strength training has limited effects on certain physical performance indicators, such as maximum strength or long-distance endurance. Improvements in certain physical performance metrics following core strength training may not be significant, potentially due to factors such as training design, training duration, players' initial fitness levels, and assessment methods. Therefore, in practical training, it is essential to tailor training strategies flexibly based on the characteristics of the specific sport and individual athlete differences.

PRACTICAL APPLICATIONS

To maximize the benefits of core strength training, it is recommended to adopt a systematic and cyclical training program. The training cycle can be set at 6 to 12 weeks, with three training sessions per week, each lasting 30 to 45 min, to avoid fatigue affecting other specialized training content. Training content should include isometric contractions and slow-controlled isometric exercises (*e.g.*, side bridges, plank holds), dynamic strength training (*e.g.*, weighted rotations), explosive power training (*e.g.*, core rotation jumps), and functional training (*e.g.*, anti-rotation exercises on balance balls or unstable surfaces) to comprehensively strengthen the various functions of the core muscle groups. Additionally, core strength training should be integrated with specific skill movements. For example, boxers should prioritize anti-rotation training to enhance striking power, while taekwondo and karate players should focus on single-leg balance and core control exercises to improve the stability and force transfer of kicks.

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Author Contributions
- Shuai Zhang performed the experiments, prepared figures and/or tables, authored or reviewed drafts of the article, and approved the final draft.
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- Kim Geok Soh analyzed the data, authored or reviewed drafts of the article, and approved the final draft.
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