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The Effects of Different Strength Training Methods on Muscle Strength and Explosive Power Performance in Combat Sports Athletes: A Systematic Review and Meta-Analysis

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Abstract:

Background: Strength training is a core method for combat sports athletes to enhance their competitive performance, but there remains controversy regarding the promotional effects of different training methods on strength and explosive power.

Objective: This study systematically compares the effects of different strength training methods on muscle strength and explosive power performance in combat sports athletes, providing a basis for formulating scientific physical training programs.

Methods: A systematic review and meta-analysis were conducted following the PRISMA guidelines, searching PubMed, Web of Science, Wiley, and Google Scholar databases with a total of 28 randomized controlled trials included (n = 631). Standardized mean differences (SMD) and 95% confidence intervals were calculated using RevMan 5.4 software, along with subgroup analyses and assessments of publication bias. The quality of included studies was evaluated using the PEDro scale (Physiotherapy Evidence Database Scale), with a total score of 10; the overall quality was moderate to high.

Results: Strength training significantly improved upper limb strength ($SMD = 0.59$, $95\%CI = 0.10 \sim 1.09$, $p = 0.02$), lower limb strength ($SMD = 0.44$, $95\%CI = 0.23 \sim 0.65$, $p < 0.01$), upper limb explosive power ($SMD = 1.01$, $95\%CI = 0.36 \sim 1.67$, $p = 0.002$), and lower limb explosive power ($SMD = 0.36$, $95\%CI = 0.18 \sim 0.55$, $p < 0.01$) in combat sports athletes. Subgroup analysis showed that ground-based combat sports ($SMD = 0.52$, $95\%CI = 0.22 \sim 0.82$, $p < 0.01$) had more significant effects on strength improvement, while stand-up combat sports ($SMD = 0.62$, $95\%CI = 0.29 \sim 0.95$, $p = 0.0002$) demonstrated greater advantages in explosive power enhancement. Comparisons of different training methods indicated that compound training ($SMD = 0.79$) was the most effective for improving muscle strength, while core strength training ($SMD = 1.27$) was the most significant for enhancing explosive power.

Conclusion: Different strength training methods can significantly improve muscle strength and explosive power in combat sports athletes. Subgroup analysis revealed that ground-based combat sports had more pronounced effects on strength enhancement, whereas stand-up combat sports showed superior advantages in explosive power improvement. Overall, compound training and core strength training represent the optimal choices for elevating strength and explosive power, respectively, providing scientific evidence for the development of physical training prescriptions in combat sports.

Keywords: Strength training, Resistance training, Combat sports athletes, Strength, Explosive power, Meta-analysis.

1 Introduction

Strength and explosive power are the foundational physical fitness elements for the competitive performance of combat sports athletes, and they also serve as important indicators for distinguishing different competitive levels (Tanghe & Martin, 2020). Combat sports events (such as judo, taekwondo, boxing, wrestling, mixed martial arts, karate, sanda, fencing, etc.) all require athletes to complete high-intensity offensive and defensive actions in extremely short periods of time, such as strikes, clinches, throws, leg sweeps, and counters. The effectiveness of these technical actions largely depends on the maximum output capacity and rapid mobilization ability of the muscular system (James et al., 2016; Lenetsky et al., 2013; Reale et al., 2020). Based on the characteristics of combat sports, they can generally be divided into two categories: stand-up combat and ground-based combat (Bridge et al., 2014; Cid-Calfucura et al., 2023). Stand-up events (such as boxing, taekwondo, sanda, karate, fencing, etc.)

67 primarily rely on explosive rapid attacks and agile footwork transitions, requiring
68 athletes to possess strong lower limb explosive power and core control to achieve
69 efficient striking and defensive actions(Beattie & Ruddock, 2022; Liu et al., 2022;
70 Moreno-Azze et al., 2023; Turner et al., 2014; Yoo et al., 2018); whereas ground-based
71 events (such as judo, wrestling, Brazilian jiu-jitsu, mixed martial arts, etc.) place greater
72 emphasis on absolute strength of the upper limbs and trunk, grip strength, sustained
73 force production ability, and muscular endurance to gain advantages in grappling or
74 control situations (Franchini et al., 2015; Øvretveit & Tøien, 2018). Research indicates
75 that muscular strength (muscular strength) determines athletes' absolute control in
76 confrontations (MAGNANI BRANCO & Franchini, 2021; Brad J Schoenfeld, 2010),
77 while explosive power (explosive power) directly influences striking speed, reaction
78 time, and the aggressiveness of actions (Wang et al., 2022). The integrated development
79 of both is a key link in enhancing specialized performance in combat sports.

80 Existing studies have indicated a significant positive correlation between athletes'
81 maximum strength levels and their specialized performance(Hermassi et al., 2011;
82 Loturco et al., 2021). For example, training of large muscle groups, such as squats,
83 bench presses, and deadlifts, can enhance punching power and impact force in boxers ;
84 lower limb strength in taekwondo athletes is significantly correlated with kicking speed,
85 explosive power, and scoring ability (Khazaei et al., 2023). Therefore, how to maximize
86 the enhancement of strength and explosive power through scientific strength training
87 methods has become a core issue in combat sports training systems. Strength training
88 induces adaptive changes in muscle structure and the nervous system through
89 systematic load stimulation, including improvements in muscle fiber recruitment rate,
90 motor unit firing frequency, tendon stiffness, and neural conduction efficiency (Del
91 Vecchio et al., 2019; Gabriel et al., 2006). In contrast, power training places greater
92 emphasis on the integrated output of speed and force, typically achieved through
93 methods such as plyometric training or velocity-based resistance training (VBRT) to
94 optimize neural activation and the stretch-shortening cycle (SSC) (Behm et al., 2025;
95 Shuai et al., 2025). Although the two differ in training logic, their goals both aim at the
96 comprehensive enhancement of muscle function.

97 In recent years, with the development of sports science, strength training methods
98 for combat sports athletes have shown a trend toward diversification(Morris et al.,
99 2022). Traditional resistance training (TRT) enhances maximum strength through
100 periodized load adjustments and is the most common training form(Santos et al., 2022);
101 plyometric training (PLYO) emphasizes explosive contraction capabilities, effectively
102 improving lower limb reactivity and jumping ability(Grgic et al., 2021); core strength
103 training (CST) focuses on trunk stability and force transmission efficiency, proven to

enhance punching speed and body balance(Zhang et al., 2025). Additionally, sport-specific strength training (SSFT) offers advantages in improving the coordination of movement patterns (Khazaei et al., 2023; Kostikiadis et al., 2018); while complex training (CT) achieves the "post-activation potentiation" effect (Blazevich & Babault, 2019) (PAP) by alternating high-load and explosive actions, making it an efficient strategy for enhancing strength and explosive power(Wang et al., 2022). At the same time, some emerging training modalities have gradually been introduced into combat sports training practices. For example, velocity-based resistance training(Baena-Marín et al., 2022; Z. Huang et al., 2025) (VBRT) optimizes the velocity-power curve by adjusting load intensity through real-time feedback; blood flow restriction training (Król et al., 2024; Miller et al., 2021; Wortman et al., 2021) (BFR) induces muscle hypertrophy and neural adaptations using low-load conditions to create a local hypoxic environment; and methods such as pneumatic resistance training (PN) and autoregulatory progressive resistance exercise (APRE) demonstrate potential in controlling training fatigue and individualization adjustments (Huang et al., 2023; Zijing Huang et al., 2025).

However, the actual effects of different training methods in combat sports athletes are inconsistent. For example, some studies suggest that plyometric training provides the most significant enhancement in explosive power, while traditional resistance training is more conducive to strength development (Oliver et al., 2024; Pardos-Mainer et al., 2021; Stojanović et al., 2017); other studies have found that complex training can simultaneously improve both within a shorter cycle(Branco et al., 2022; Osipov et al., 2021). The differences in results between studies may arise from factors such as training load, frequency, duration, differences in sports events, and sample levels, thus necessitating integration and comparison through systematic review and meta-analysis. This study, building on existing literature, strictly adheres to the PRISMA 2020 guidelines for study selection, data extraction, and reporting to ensure transparency and reproducibility. For the first time, it incorporates the sports characteristics of combat events by distinguishing between stand-up and ground-based combat athletes to explore differences in training responses across different types of events; furthermore, it conducts a horizontal comparison of traditional resistance training, plyometric training, core training, functional training, complex training, and emerging strength training within the same framework. By ranking effect sizes, it clarifies the priority selections among different training methods, providing evidence-based rationale and theoretical support for physical training in combat sports.

2. Method

2.1 Protocol and Registration

The meta-analysis was conducted and reported according to the PRISMA guidelines to ensure comprehensive and transparent reporting of our methods and results (Moher et al., 2009). The study protocol has been registered on the PROSPERO platform. Registration number: CRD420251063019.

2.2 Literature Search Strategy

This study searched four databases: PubMed, Web of Science, Wiley, and Google Scholar, with a cutoff date of September 1, 2025. Except for Google Scholar, which applied a time filter (2015–2025), the other databases did not use filters. Taking Google Scholar as an example, the search terms included: ("strength training" OR "resistance training" OR "power training" OR "explosive strength training" OR "plyometric training" OR "different training methods") ("combat sports" OR "martial arts" OR "MMA" OR "mixed martial arts" OR "fighters" OR "combat athletes") ("muscular strength" OR "maximal strength") ("explosive power" OR "power output" OR "explosive strength"). In addition, potential related articles were supplemented through manual searching of the references from the included studies. For the detailed search strategy, please refer to the appendix.

2.3 Inclusion and Exclusion Criteria

Based on the "PICOS" strategy, the inclusion criteria were as follows: (1) Study subjects were combat sports athletes without injury or disease; gender and race unrestricted; (2) Intervention was a strength training program; (3) Control group involved routine training or no weightlifting training, or other forms of strength training; (4) Reported specific exercise performance data related to strength or explosive power; (5) Study type was randomized controlled trial (RCT), including crossover or parallel designs.

Exclusion criteria: (1) Study subjects were non-combat sports athletes, patients with diseases, rehabilitation populations, or animal experiments; (2) Did not clearly adopt a weightlifting training program, or the training program did not involve squat, deadlift, or bench press movement patterns; (3) Did not report quantitative data related to strength or explosive power, or only provided qualitative descriptions; (4) Conference abstracts, review articles, book chapters, case reports, or literature in non-English and non-Chinese languages; (5) Original data incomplete, unable to extract, or unable to obtain the required data by contacting the authors.

2.4 Literature Screening Process

The screening process strictly followed the PRISMA guidelines. All retrieved record information was imported into EndNote 21 software for deduplication, and Excel was used for data management and extraction of literature information. The screening was conducted in two stages: First, two independent reviewers excluded studies that obviously did not meet the criteria based on predefined inclusion and exclusion standards by reviewing titles and abstracts. When necessary, full texts were obtained for further evaluation. Second, for the literature that passed the initial screening, two reviewers independently reviewed them to confirm compliance with the inclusion criteria, with discrepancies resolved through discussion with a third reviewer. Additionally, relevant literature was supplemented by manually searching the references of the included studies. If the data in the literature was incomplete, reviewers contacted the authors to obtain the missing information; studies with no response after one week were excluded from the review and meta-analysis.

2.5 Data Extraction

The titles and abstracts of the searched studies were independently reviewed to exclude obviously irrelevant studies. Full-text studies were then included based on the selection criteria. Detailed data were extracted by one reviewer into a prepared table, and the accuracy of the data was checked by a second reviewer. Disagreements between reviewers were discussed to reach a consensus. The following information was collected: (1) Basic study information (authors, year, sample size); (2) Study design characteristics; (3) Basic characteristics of the study subjects; (4) Strength training program and training frequency; (5) Primary outcome indicators.

The methodological quality of the included studies was assessed using the Physiotherapy Evidence Database (PEDro) scale. The PEDro scale includes 11 assessment items, of which items 2–11 are scored, with a total score of 10. Scores < 4 indicate poor quality, 4–5 indicate moderate quality, 6–8 indicate good quality, and 9–10 indicate high quality. Two reviewers (FWW and XJ) independently scored the studies, and discrepancies were resolved through discussion or consultation with a third author (MFY).

2.6 Data Analysis

RevMan 5.4 software was used for statistical analysis of the included literature. To evaluate the intervention effects of different training methods, the standardized mean difference (SMD) was adopted as the effect size indicator, and its statistical significance could be interpreted using Cohen's *d* values. According to Cohen (1988) standards: $d < 0.2$ indicates a small effect size, $0.2 \leq d < 0.5$ indicates a medium effect, $0.5 \leq d < 0.8$ indicates a large effect, and $d \geq 0.8$ indicates a very large effect.

Referring to the Cochrane Handbook for Systematic Reviews, p-values and I^2 were used for quantitative heterogeneity analysis. I^2 represents the level of heterogeneity between studies, ranging from 0% to 100%. When $I^2 = 0\%$, there is no heterogeneity between studies. When I^2 is 0%–25%, there is small heterogeneity between studies, which can be ignored. When $I^2 = 25\%$ –50%, there is low heterogeneity; when $I^2 = 50\%$ –75%, there is moderate heterogeneity; when $I^2 = 75\%$ –100%, there is substantial heterogeneity that cannot be ignored. When $I^2 \leq 50\%$, a fixed-effects model was used for the meta-analysis (Rendina-Gobioff, 2006); otherwise, a random-effects model was used (Barili et al., 2018), and subgroup analyses were conducted to identify and determine the mediating variables causing heterogeneity. If $p < 0.05$, statistical significance was considered present; otherwise, it was not. To verify the reliability of the results, sensitivity analysis was performed using a fixed-effect model, sequentially removing individual studies to observe changes in the pooled effect size and assess whether any single study significantly influenced the overall results.

3. Outcome

3.1 Literature Screening Results

A total of 4448 literature records were obtained through database searches, including: PubMed (n=872), Web of Science (n=150), Wiley (n=236), and Google Scholar (n=3190). After removing 2113 duplicate records, 2335 records proceeded to the title and abstract screening stage. During the title and abstract screening process, 2101 records that did not meet the inclusion and exclusion criteria were excluded based on the standards. Subsequently, 234 full-text articles were evaluated for eligibility. After evaluation, the following were excluded: non-randomized controlled trials (n=54), non-strength training studies (n=23), non-combat sports athlete studies (n=59), incomplete data (n=68), and non-English literature (n=2). Ultimately, 28 studies met the inclusion criteria and were included in the qualitative analysis of the systematic review.

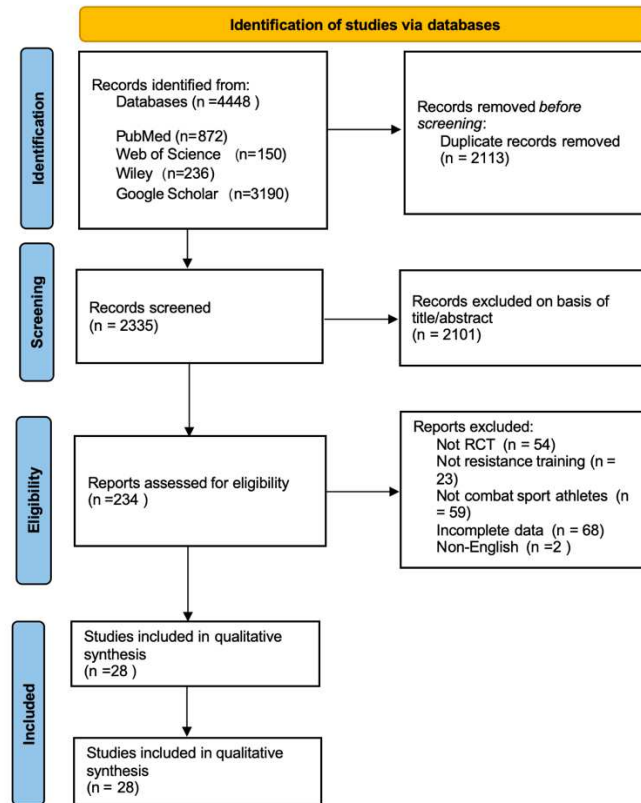


Figure 1 Flowchart of the literature screening process

3.2 Basic Characteristics of Included Studies

This study ultimately included 28 studies, with subjects being combat sports athletes from events such as judo, taekwondo, karate, boxing, mixed martial arts, martial arts, wrestling, and fencing. A total of 631 participants (330 in the experimental group, 301 in the control group), aged 12–35 years, encompassing adolescent and adult male and female athletes. The interventions were diverse, primarily including: traditional resistance training (TRT), plyometric training (PLYO), velocity-based resistance training (VBRT), autoregulatory progressive resistance exercise (APRE), blood flow restriction training (BFR), pneumatic resistance training (PN), maximum strength training (MST), functional training (FT), eccentric training (ECC), core strength or core stability training (Core/IS), etc.; as well as various complex training (Complex Training) modes, such as "traditional resistance + plyometric," "plyometric + sport-specific," "strength + judo training," "core + sport-specific training," and others. Training durations ranged from 4–12 weeks, with frequencies mostly 2–4 times per week, and some studies up to 5–6 times per week. Intensities were generally controlled at 50%–90% 1RM, with most studies having inter-set rest times of 1–3 minutes. Control group interventions mainly consisted of usual simulated training or standard combat training. Outcome indicators primarily focused on: strength outcomes (e.g., 1RM, peak torque (Knee Extension 60°/s), isometric strength (IS),

258 Leg Strength (kg)); power outcomes (e.g., CMJ, SJ, SLJ, PP, PPO, Leg Power (W/N)); and
259 sport-specific performance (e.g., Punch Velocity, Rear Hand Punch Power (RHPP), Seated
260 Medicine Ball Throw (SMBT), Overhead Medicine Ball Throw (OMBT)). Specific
261 characteristics are shown in Table 1.

Table 1 Characteristics of included studies

study	Study design	Type of athletes	Sample size (EG/CG)	Age (yrs)	Experimental intervention	Control intervention	Exercises and methods	Sets/repetitions/load/rest between sets	Training frequency & duration	Outcome measures
(Boyat, Singh, & Sandhu, 2017)	RCT	Taekwondo athletes (national level)	10/10 (all M)	18-21	TRT+PLYO	RT	TRT: Bench press, leg press, front press, and leg curl. PLYO tuck jumps, medicine ball (3kg) overhead throws, hurdle jumps, and MB seated throws.	Weeks 1-3: $3 \times 8 \times 55\%$ 1RM (1 min); Weeks 4-6: $3 \times 10 \times 60\%$ 1RM (1 min)	3 sessions / week $\times$ 6 week	MBP, VJ
(Osipov et al., 2021)	RCT	Elite judo athletes	24/12 (all M)	17	CrossFit + Resistance	Resistance + circuit	CrossFit + Resistance Training: Sprints, barbell squats, push-ups, kettlebell swings, weighted walking, planks, etc.	Group 1: $4-5 \times 8-12 \times 70-85\%$ 1RM (2-3 min); Group 3: 7-8 ex $\times 4$ min $\times 10$ rounds (2-2.5 min)	4 sessions / week $\times$ 12 week	BP, BS, SJ
(Øvretveit & Tøien, 2018)	RCT	Brazilian Jiu-Jitsu	7/7 (all M)	30	MST+RT	RT	Squats, bench presses, and pull-ups to failure.	$4 \times 4 \times \geq 85\%$ 1RM (3 min)	3 sessions / week $\times$ 4 week	BP, SQ, CMJ
(Redondo, Alonso, Sedano, & de Benito, 2014)	RCT	Fencers (national level)	6/6 (all M)	22-25	TRT+PLYO	RT	Bench press, squats, seated calf raises. Combined resistance and flexibility training: squats + vertical jumps, bench press + barbell push-ups, seated calf raises + straight-leg jumps.	Traditional: $3 \times 6 \times 75\%$ 1RM (3 min); Plyometric: 3 sets $\times$ (3 $\times$ 70% 1RM + 6 body-weight reps) (3 min)	2 sessions / week $\times$ 12 weeks (+ 5-6 fencing sessions / week)	BP, SQ, CMJ
(Franchini et al., 2015)	Quasi-experimental	Judo athletes	6/7 (all M)	18-35	Linear periodized strength training	Undulating periodization	Bench press, squat, barbell row, arm curl, lying triceps extension, leg curl, barbell wrist curl, dumbbell forehead raise, dumbbell lateral raise, good morning, reverse wrist curl and Smith standing leg raise.	1-2 week: $4 \times 3-5$ RM; 3-5 week: $4 \times 6-8 \times 80\%$ 1RM; 6-8 week: 15-20 RM	3 sessions / week $\times$ 8 weeks (+5 judo sessions / week)	BP, SQ, SLJ
(Khazaei et al., 2023)	RCT	Elite Taekwondo athletes	9/8 (all F)	21.7	FT	TRT	FT: burpees, barbell squats and calf raises, medicine ball alternating push-ups, snatches, clean and jerk, lunges with medicine ball, single-leg kettlebell deadlifts, etc. TRT: Smith squats, barbell bench presses, leg extensions, leg curls, shoulder presses, cable lateral raises, etc.	$3-5 \times 6-14 \times 50-80\%$ of 1RM (1-2 min rest)	3 sessions / week $\times$ 8 weeks (75-90 min)	BP, PP

(Zijing Huang et al., 2025)	RCT	University Taekwondo athletes	15/1516F4M)	20	APRE	VBRT	Squat, bench press, deadlift, push-up.	APRE based on 4 RM; VBRT 60–85% 1RM velocity-threshold adjusted (2–3 min rest)	3 sessions / week × 8 week	SQ、CMJ
(Paulauskas, Pundzevicius, & Figueira, 2025)	RCT	Taekwondo athletes	11/10 (all M)	14-16	Elastic resistance incremental kick training	RT	Elastic resistance incremental roundhouse kick training.	3 sets × 6 reps per leg; 30 s between kicks, 3 min between sets	4 sessions / week × 8 weeks (90 min)	IS、CMJ
(Kostikiadis et al., 2018)	RCT	MMA athletes (national level)	10/7 (all M)	26-29	Sport-specific strength & conditioning training	RT	Squats, bench presses, deadlifts, CMJ, medicine ball throws, jumping shrugs, rowing machine, weighted jump squats, drop jumps, medicine ball straight punch throws, plyometric pushups, weighted sled sprints, unweighted sprints, 40m shuttle sprints (SIT).	3–5 × 2–8 × 80–95% 1RM (3 min rest)	3 sessions / week × 4 weeks (+3 skill sessions)	BP、SQ、SLJ
(Kamal, 2015)	RCT	Karate athletes	10/10 (all F)	12.5	CST	RT	Swiss ball, sitting exercises, balance board, core stability exercises..	3–5 circuits alternating exercise and rest	10 weeks	IS、SLJ
(Brown, 2021)	RCT	Professional boxing athletes	10/10 (all M)	24.2	Core stability + isometric resistance training	RT	Plank, Side Plank, Bird Dog, Single-Leg Hip Bridge, Side Twist, Pullovers, Band Static Hold.	2-5 sets of each exercise, isometric hold 30s-3 min or 10-20 times, increasing the load weekly; rest 30s	2 sessions / week × 6 weeks	RHPP
(Huang et al., 2023)	RCT	Youth female judo athletes	9/10 (all F)	13–16	PN	TRT	Back squat.	4*8*70%1RM*90-120s	2 sessions / week × 6 weeks	SQ、CMJ
(Jiang, Che, Zhang, & Li, 2025)	RCT	Youth wrestling athletes	16/8 (all F)	17	BRFT+RT	RT	Bench press, deadlift, pull-ups, core training.	1-4 Week : 5 minutes work/15 minutes rest 5-7 Week: 7.5 minutes work/12.5 minutes rest 8-10 Week: 10 minutes work/10 minutes rest	3 sessions / week × 6 weeks	SJ
(Singh, 2015)	RCT	Taekwondo athletes	15/15 (all M)	22.0	PLYO	RT	Lateral ankle jump, standing long jump, double-leg jump, hurdle jump, single-leg jump, cone jump, Hexagon drill, etc.	2-5 sets * 6–16 * 2–3 min, progressing from low to medium to high intensity	3 sessions / week × 6 weeks	VJ
2017(Wongputthichai, 2017)	Quasi-experimental	Muay Thai athletes	17/16 (all M)	18-25	PLYO+RT	RT	Squat jumps, over back toss, lateral hurdle jumps, side throws, lateral high hops, plyometric push-ups, zigzag jumps, slams.	3 sets of 8–10 reps at 85%–100% HRmax	2 sessions / week × 12 weeks (+5 RT)	KE 60°/s、KE 180°/s

(Uzun, 2017)	RCT	Judo athletes	15/15 (all M)	21.40	PLYO+RT	RT	NR		3 sessions / week×10 weeks	Leg strength (kg)
(Nowakowska, 2017)	RCT	Karate athletes	10/9 (all M)	15–19	PLYO	RT	Push-ups over plate, Vertical depth jumps, Burpees, Vertical depth jumps , Medicine ball step to chest pass, Power skipping over hurdles, Resistance band lateral raises, Alternate leg lateral jumps.	Perform each exercise to exhaustion, rest for 2–3 minutes, and do about 3 sets; increase the load week by week.	4 sessions / week×8 weeks	PP
(Kurniawan, 2021)	Quasi-experimental	Judo athletes	11/11 (all M)	21–24	PLYO+RT	RT	NR	NR	4 sessions / week×8 weeks(90min)	Leg power (N)
(Moreno-Azze et al., 2023)	RCT	Karate athletes	10/10 (all M)	19	PLYO	RT	Drop Jump (20 cm), CMJ, Single-leg Hop; gradually increase the number of sets and reps, combined with regular karate training.	2-4 × 4-8 reps per leg	1 sessions / week×6 weeks (+4 RT)	CMJ
(Ioannides, 2020)	RCT	Karate athletes	6/6 (2F10M)	17	PLYO+RT	RT	Drop jumps, Hurdle jumps, Box jumps, long jumps, Seated medicine ball throw 1kg.	Drop jumps & hurdle jumps (Weeks 1–2: 4×4, Weeks 3–4: 4×6, Weeks 5–6: 4×8)	2 sessions / week×6 weeks (+4-5 RT)	IPT、CMJ
(Genç, 2021)	RCT	Taekwondo athletes	10/10 (all M)	20	PLYO+RT	RT	Drop jump, box jump, squat jump, split squat jump, overhead slam, plyometric push-ups.	3 × 10 reps/set for the first 4 weeks, 90s rest; 4 × 10 reps/set for the second 4 weeks, 90s rest	3 sessions / week×8 weeks	VJ
(Król et al., 2024)	RCT	MMA athletes	15/15 (all M)	19–42	BFR	TRT	Barbell squats, dumbbell lunges, and leg press machine.	20% 1RM, 30 reps → 15 reps → 15 reps → 15 reps (75 reps/set) Rest 45-120s	3 sessions / week×8 weeks	SQ
(Dallas, Pappas, Ntallas, Paradisis, & Exell, 2020)	RCT	Wrestling athletes	8/8 (all M)	16.8	CST+RT	RT	Forearm plank, side plank, reverse plank, standing single-arm dumbbell hold	3 sets, hold for 30–60s, rest 1–2 min	3 sessions / week×4 weeks	OMBT (m)
(Branco et al., 2022)	RCT	Youth judo athletes	8/8 (all M)	15.5	TRT+RT	RT	Snatch, clean and jerk, deadlift, bench press, rowing, half squat machine, combined with core support (plank support, side bridge, bridge type), elastic band into the body movement, rope up and down , etc.	Week 1: A (3×3, 120s), B (3×8, 60s); Week 8: A (5×12, 90s), B (5×12, 90s)	3 sessions / week×8 weeks	BP、HSQ、CMJ

(Soyler et al., 2025)	RCT	Boxing athletes (national level)	10/10 (all M)	21.2	Plyometric Step Jump group	Plyometric Rebound Jump group	Step jumps (alternating single-leg step jumps + CMJ).	3 -5sets × 8 reps ×2min	3 sessions / week×8 weeks(+5 RT)	BP, Maximum Punching Velocity
(di Cagno et al., 2020)	RCT	Elite male foil fencers	26/28 (all M)	17.3	ECC	PLYO	Lunges, advance-advance lunges and other specialized fencing moves..	3-4 sets×8-10 reps×2min	2 sessions / week×6 weeks	CMJ
(Tian, 2022)	RCT	Wushu athletes	11/6 (all M)	NR	TRT	RT	Weighted squats and half squats	NR	6 weeks	HSQ
(Bu, 2022)	RCT	Wushu athletes	(10/10, all F)	21–23	Power training	TRT	Weighted straight punch, narrow jump push-ups, alternating one-arm push-ups.	4 sets × 8–12 reps×2min	3 sessions / week×12 weeks	SMBT、PV

264 (Note: APRE = Autoregulated Progressive Resistance Exercise; BFRT = Blood Flow Restriction Training; BFR = Blood Flow Restriction; BP
265 = Bench Press; BS = Back Squat; CMJ = Countermovement Jump; CST = Core Strength Training; ECC = Eccentric Training; EG =
266 Experimental Group; FT = Functional Training; HRmax = Maximum Heart Rate; HSQ = Half Squat; IS = Isometric Strength; KE 60°/s = Knee
267 Extension at 60 degrees per second (leg strength indicator); KE 180°/s = Knee Extension at 180 degrees per second (leg power indicator); MBP
268 = Medicine Ball Power; MMA = Mixed Martial Arts; MST = Maximal Strength Training; NR = Not Reported; OMBT = Overhead Medicine
269 Ball Throw; PLYO = Plyometric Training; PN = Pneumatic Resistance Training; PP = Peak Power; PV = Punch Velocity; RHPP = Rear Hand
270 Punch Power; RT = Routine Training; SJ = Squat Jump; SLJ = Standing Long Jump; SMBT = Seated Medicine Ball Throw; SQ = Squat; TRT =
271 Traditional Resistance Training; 1RM = One Repetition Maximum.)

3.3 Quality Assessment of Included Studies

Methodological quality assessment of the 28 included studies was conducted using the PEDro scale (Table 2), with scores ranging from 4 to 7, an average score of 5.32, indicating an overall quality level of moderate to high. Among them, most studies performed well in terms of randomization, baseline comparability, and outcome reporting, but the majority did not clearly specify allocation concealment and blinding implementation, and sample sizes were generally small. Overall, the included studies have relatively standardized designs, acceptable risk of bias, and can provide a reliable basis for subsequent meta-analysis.

Table 2 Quality assessment of included studies using the Cochrane Risk of Bias Tool

Study	1	2	3	4	5	6	7	8	9	10	11	PEDro 总分
Boyat, 2017	1	0	1	1	0	0	0	1	1	1	1	6
Osipov, 2021	1	1	0	1	0	0	0	1	1	1	1	6
Karsten, 2018	1	1	0	1	0	0	0	1	1	1	1	6
Redondo,2014	1	1	0	1	0	0	0	1	0	1	1	5
Franchini, 2015	1	1	0	1	0	0	0	1	0	1	1	5
Khazaei, 2023	1	1	0	1	0	0	0	1	0	1	1	5
Huang, 2024	1	1	0	1	0	0	0	1	0	1	1	5
Paulauskas, 2025	1	1	1	1	0	0	0	1	1	1	1	7
Kostikiadis, 2018	1	1	0	1	0	0	0	1	1	1	1	6
Kamal, 2015	1	1	0	1	0	0	0	1	0	1	1	5
Brown, 2021	1	1	0	1	0	0	0	1	0	1	1	5
Huang, 2023	1	1	1	1	0	0	0	1	1	1	1	7
Jiang , 2025	1	1	0	1	0	0	0	1	0	1	1	5
Singh, 2015	1	1	0	1	0	0	0	1	0	1	1	5
Wongputthichai, 2017	1	1	0	1	0	0	0	1	1	1	1	6
Uzun & Karakoc, 2017	1	1	0	1	0	0	0	1	0	1	1	5
Nowakowska,2017	1	1	0	1	0	0	0	1	0	1	1	5
Kurniawan, 2021	1	1	0	1	0	0	0	1	0	1	1	5
Moreno-Azze, 2023	1	1	0	1	0	0	0	1	0	1	1	5

Ioannides, 2020	1	1	0	1	0	0	0	1	0	1	1	5
Genç & Dağlıoğlu, 2021	1	1	0	1	0	0	0	1	1	1	1	6
Król, 2024	1	1	0	1	0	0	0	1	0	1	1	5
Valipour Dehnou, 2019	1	1	0	1	0	0	0	0	0	1	1	4
Branco, 2022	1	1	0	1	0	0	0	0	0	1	1	4
Soyler, 2025	1	1	0	1	0	0	0	1	0	1	1	5
di Cagno , 2020	1	1	0	1	0	0	0	1	0	1	1	5
Tian, 2022	1	1	0	1	0	0	0	1	0	1	1	5
Bu , 2022	1	1	0	1	0	0	0	1	1	1	1	6

Note:1: Specify eligibility criteria; 2: Subjects randomly allocated to groups; 3: Allocation concealed; 4: Groups similar at baseline; 5: All subjects blinded; 6: All therapists blinded; 7: All assessors blinded; 8: Measurements obtained from >85% of subjects allocated to groups; 9: Subjects received allocated treatment or control condition, or intention-to-treat analysis; 10: Report of between-group statistical comparisons for at least one outcome; 11: Report of point measures and measures of variability. 0: High risk of bias; 1: Low risk of bias; total score is the sum of each "1" counted.

3.4 Meta-analysis Results

This study conducted a meta-analysis on the effects of different strength training methods on strength and explosive power performance in combat sports athletes from the included literature, while distinguishing between upper and lower limb muscle strength and explosive power and also performing subgroup analyses based on combat types.

3.4.1 Effects of Strength Training on Muscle Strength

The meta-analysis results showed that strength training had a significant positive effect on upper limb muscle strength ($n = 10$, $SMD = 0.59$, $95\%CI = 0.10 \sim 1.09$, $p = 0.02$) and lower limb muscle strength ($n = 19$, $SMD = 0.44$, $95\%CI = 0.23 \sim 0.65$, $p < 0.01$) in combat sports athletes, indicating that strength training promotes the enhancement of maximum strength in combat sports athletes (Figure 2&3). Upper limb strength mainly includes 1RM bench press and punching force, while lower limb strength mainly includes 1RM squat, half-squat, Isometric Peak Torque, and knee extension 60°/s concentric contraction. Heterogeneity tests showed that upper limb muscle strength $I^2 = 59\%$ was relatively high, thus a random-

effects model was used; lower limb $I^2=37\%$ was relatively low, thus a fixed-effects model was used.

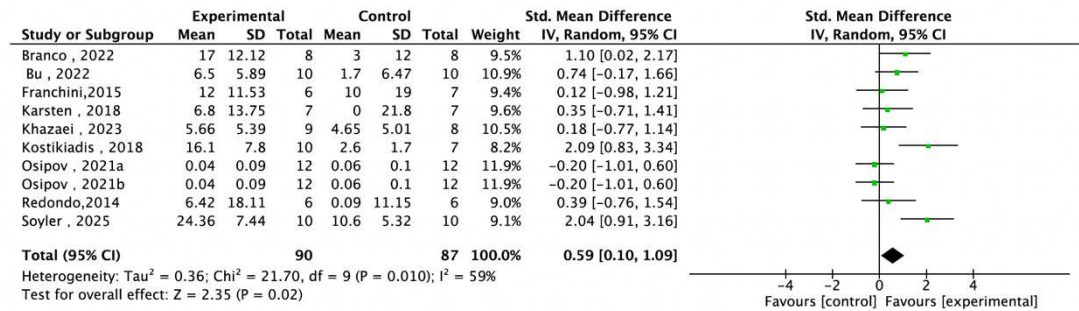


Figure 2 Forest plot showing the effects of strength training on upper-limb muscular strength in combat athletes.

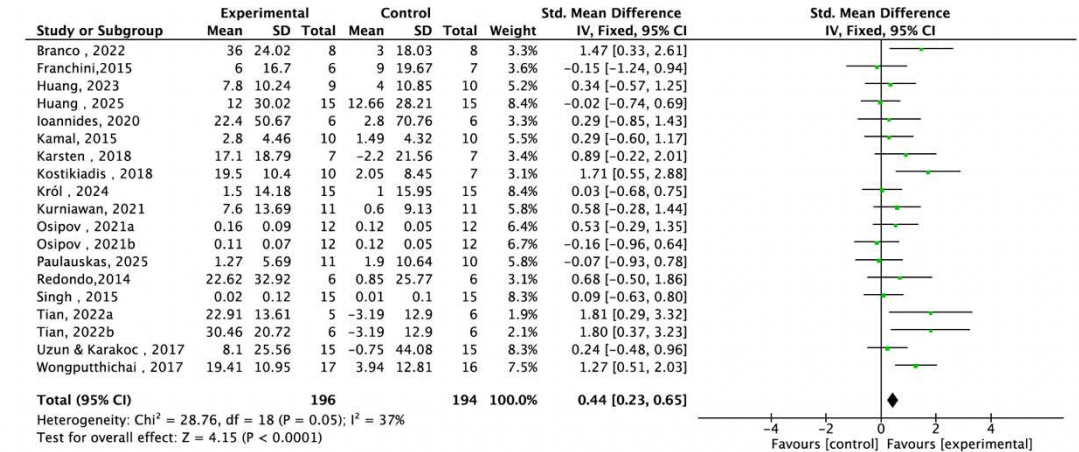


Figure 3 Forest plot showing the effects of strength training on lower-limb muscular strength in combat athletes.

3.4.2 Effects of Strength Training on Explosive Power

The meta-analysis results showed that strength training had a significant positive effect on upper limb explosive power ($n = 6$, $SMD = 1.01$, $95\%CI = 0.36 \sim 1.67$, $p = 0.002$) and lower limb explosive power ($n = 22$, $SMD = 0.36$, $95\%CI = 0.18 \sim 0.55$, $p < 0.01$) in combat sports athletes, indicating that strength training promotes the enhancement of explosive power in combat sports athletes (Figure 4&5). Upper limb explosive power mainly includes MBP (m), Peak Power (PP, W/kg), Maximum Punching Velocity rear arm, seated medicine ball throw (m), rear hand punch impact power (Watt, W), and front throw (m); lower limb explosive power mainly includes CMJ, SJ, SLJ, etc. Heterogeneity tests showed that upper limb explosive power $I^2=61\%$ was relatively high, thus a random-effects model was used;

lower limb explosive power $I^2=33\%$ was relatively low, thus a fixed-effects model was used.

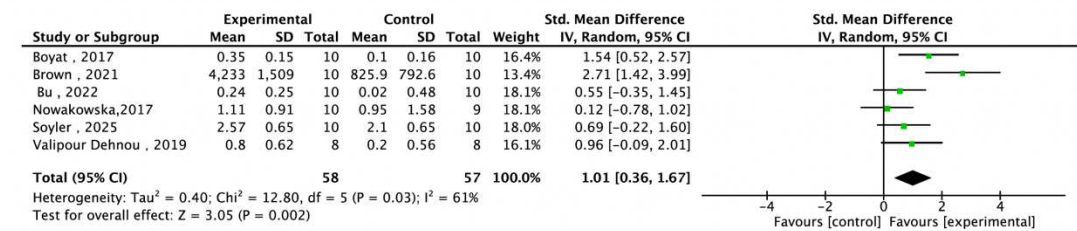


Figure 4 Forest plot showing the effects of strength training on upper-limb explosive power in combat athletes.

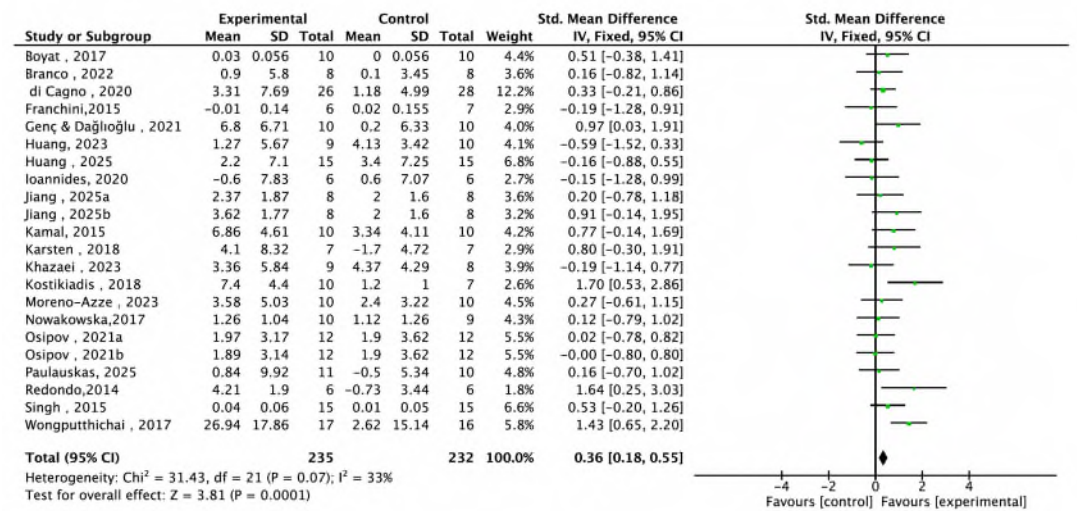


Figure 5 Forest plot showing the effects of strength training on lower-limb explosive power in combat athletes.

3.4.3 Subgroup Analysis: Differences by Combat Type

To explore the effects of different combat types on strength training outcomes, this study categorized the included studies into two types based on combat sports characteristics: stand-up combat events (such as taekwondo, boxing, karate, sanda martial arts, fencing) and ground-based combat events (such as judo, wrestling, Brazilian jiu-jitsu, mixed martial arts). Subgroup analysis results showed differences in the magnitude of improvements in strength and explosive power between the two categories.

For strength indicators (Figure 6), ground-based combat athletes showed greater improvements in strength ($n = 9$, $SMD = 0.52$, $95\%CI = 0.22 \sim 0.82$, $p < 0.01$) compared to stand-up combat ($n = 11$, $SMD = 0.51$, $95\%CI = 0.24 \sim 0.79$, $p < 0.01$). This indicates that ground-based combat events rely more on absolute strength and sustained muscle force output, making weightlifting or high-load resistance training more directly beneficial.

For explosive power indicators (Figure 7), stand-up combat athletes ($n = 16$, $SMD = 0.62$, $95\%CI = 0.29 \sim 0.95$, $p = 0.0002$) showed better improvement effects compared to ground-based combat ($n = 9$, $SMD = 0.56$, $95\%CI = 0.21 \sim 0.91$, $p = 0.002$). This difference may be related to movement characteristics: stand-up combat requires rapid initiation, striking, and reaction speed, while ground-based combat emphasizes static confrontation and sustained force exertion.

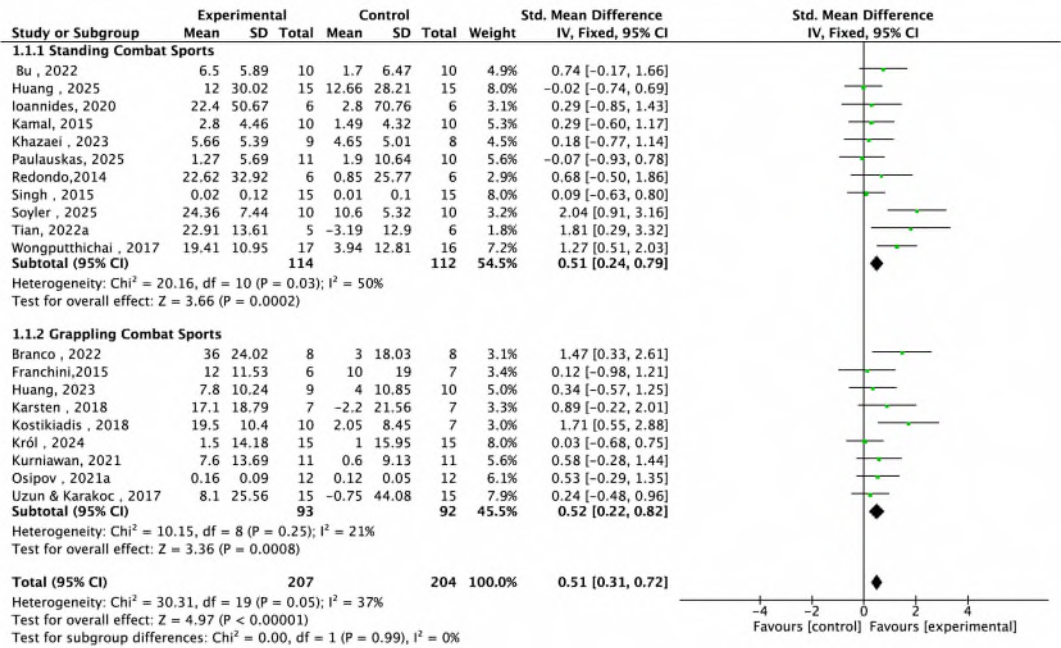


Figure 6 Subgroup analysis of muscular strength by combat type (stand-up vs ground-based).

Figure 7 Subgroup analysis of explosive power by combat type (stand-up vs ground-based).

3.5 Comparison of Effects of Different Strength Training Methods

To further explore the differences in the effects of different strength training methods on physical performance in combat sports athletes, this study conducted subgroup analyses based on training modalities, primarily including: Traditional

Resistance Training (TRT), Plyometric Training (PLYO), Sport-Specific and Functional Training (SSFT), Core Strength Training (CST), Emerging Strength Training Methods (EST), Combined or Hybrid Strength Training (CT / HST), and other six categories. The analysis results are as follows:

For muscle strength effect ranking: CT (0.79) > PLYO (0.62) > SSFT (0.55) > TRT (0.41) > EST (0.30) > CST (0.29), so complex training is the best.

For explosive power effect ranking: CST (1.27) > CT (0.85) > EST (0.64) > PLYO (0.54) > SSFT (0.40) > TRT (0.08).

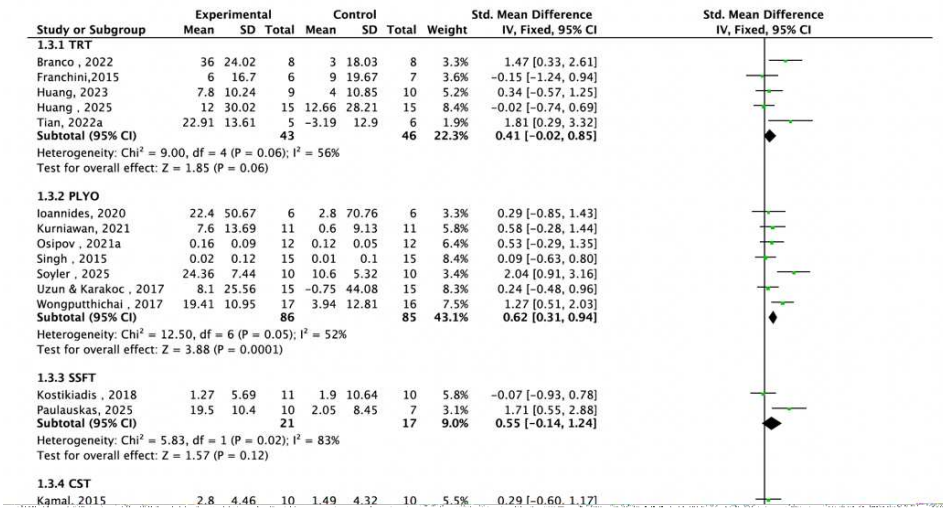


Figure 8 Comparison of different strength training methods on muscular strength in combat athletes.

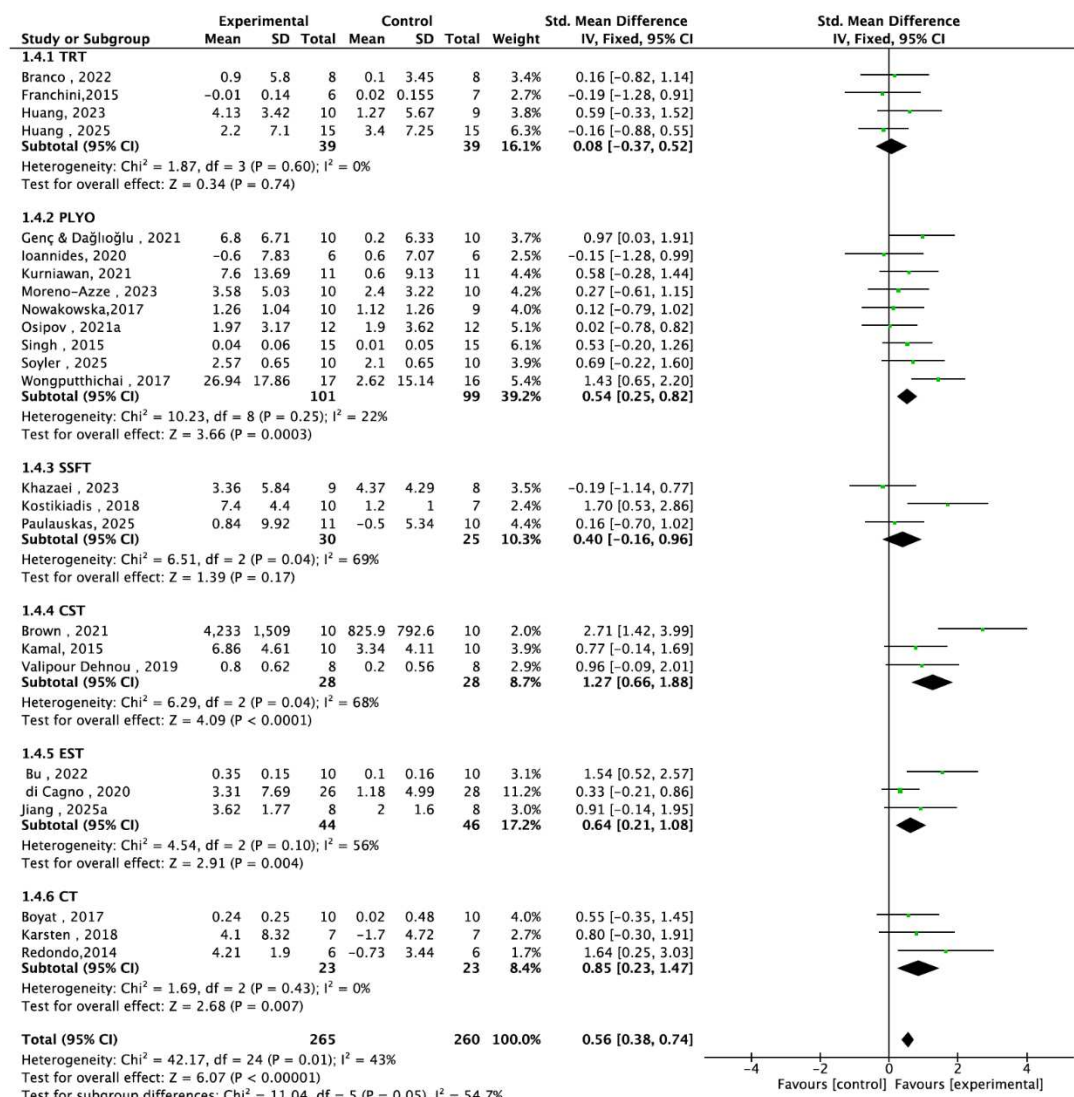


Figure 9 Comparison of different strength training methods on explosive power in combat athletes.

3.6 Publication Bias Risk Analysis

The funnel plot (Figure 10) illustrates the distribution of effect sizes and standard errors across studies. Most study points are distributed near the symmetry axis of the funnel plot, presenting a relatively balanced shape without obvious asymmetry, suggesting a low risk of publication bias. However, a few studies are located at the edges of the funnel plot, which may reflect high variability in small-sample studies or potential selective reporting risks.

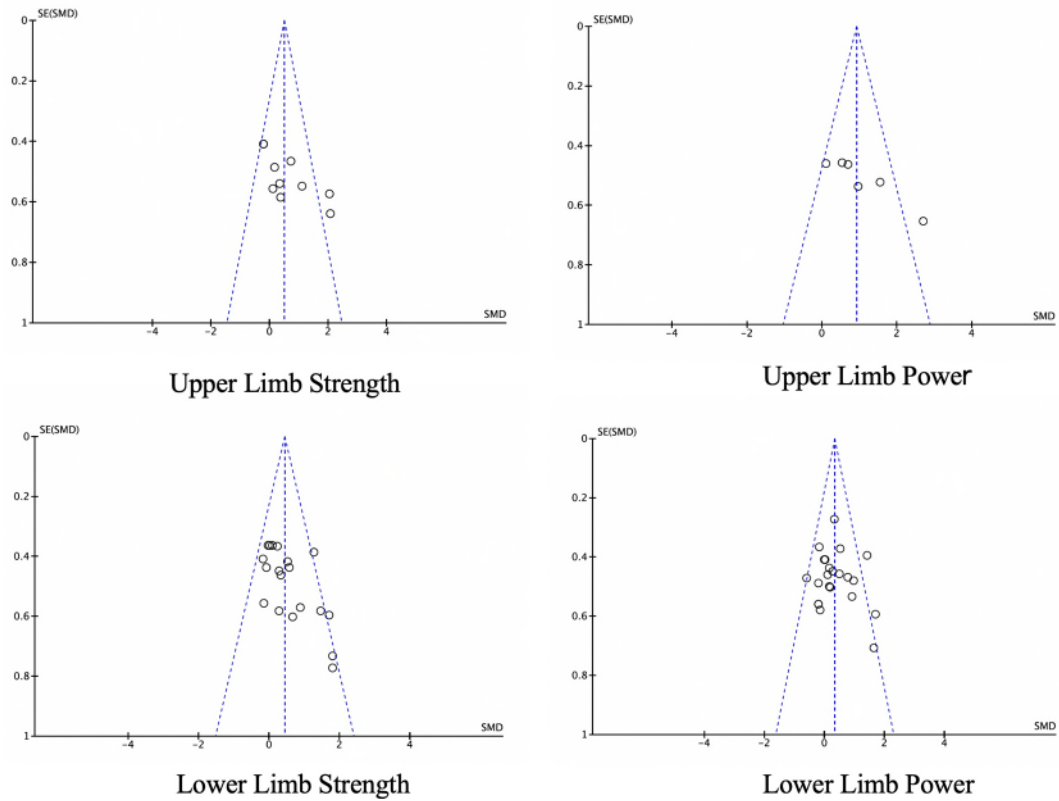


Figure 10 Funnel plot for publication bias assessment.

4. Discussion

The purpose of this study is to explore the effects of different strength training methods on muscle strength and explosive power performance in combat athletes, providing guidance for combat sports training. Overall, strength training exerts a dual promotional effect on the physical functions of combat athletes. On one hand, it stimulates muscle hypertrophy and neural adaptations through mechanical tension and metabolic stress, thereby increasing maximum strength reserves (Carvalho et al., 2022; B. J. Schoenfeld et al., 2017; B. J. Schoenfeld et al., 2016); on the other hand, by enhancing motor unit recruitment rates and neural firing frequencies, it improves the rate-dependent characteristics of force output, thus boosting explosive power performance (Cui et al., 2025). Research by Aagaard et al. indicates that strength training can enhance neuromuscular control capabilities and motor unit synchronization levels in the short term, enabling muscles to generate higher peak power output in shorter durations—a mechanism that aligns highly with the demands of short-duration, high-intensity offensive and defensive actions in combat sports (Aagaard, 2003). Additionally, strength training can improve force transmission and movement coordination by increasing tendon stiffness and enhancing core stability, thereby elevating overall movement efficiency.

Subgroup analysis results reveal significant differences in strength effects between stand-up combat and ground combat, a phenomenon likely stemming from variations in sport specificity and strength demands. On one hand, stand-up combat requires terminal ballistic release, while ground combat demands absolute strength, potentially accounting for this disparity. On the other hand, stand-up combat athletes must rapidly initiate and terminate actions during confrontations, with weightlifting training providing a foundational base for these explosive movements by strengthening lower limb and core power. In contrast, ground combat relies more on technique and endurance. Franchini's research demonstrates (Franchini et al., 2015) that following improvements in bench press and squat 1RM among judo athletes, no significant changes were observed in explosive power tests (CMJ), possibly because ground combat emphasizes dynamic balance and sustained force exertion rather than static maximum strength. Furthermore, the influence of weight classes further clarifies these differences: higher weight classes depend more on absolute strength (i.e., ground combat athletes), while lower weight classes rely more on explosive power, flexibility, and rhythm (i.e., stand-up combat). In combat sports, athletes in higher weight classes depend more heavily on absolute strength to dominate opponents, as their matches typically involve prolonged force application and physical superiority (Detanico et al., 2012; Harris et al., 2020; Kasim et al.; Tuba et al., 2012).

The mechanisms by which different strength training methods promote strength and explosive power also differ. Complex training, by alternating high-load resistance exercises with explosive actions (e.g., squat-jump combinations) within the same session, induces the "post-activation potentiation effect (Garbisu-Hualde & Santos-Concejero, 2021)" (Post-Activation Potentiation, PAP), enhancing neural excitability and muscle contraction velocity, thereby simultaneously advancing both strength and explosive power (Li et al., 2024). Existing studies show that complex training can significantly improve maximum strength and vertical jump performance in a short period, demonstrating its pronounced facilitative role in neuromuscular activation (Krzysztofik et al., 2025; Liu et al., 2024; Qiao et al., 2022). For combat athletes, this method is particularly suitable for specialized physical conditioning in the pre-competition phase, aiding in the transfer of strength to movement speed.

Core strength training demonstrated the optimal effect on explosive power enhancement in this study. The core region serves as the hub for force transmission between the upper and lower limbs, playing critical roles in stability, support, and transfer during combat movements (Granacher et al., 2014). Enhancing core strength can improve body stability, increase force transmission efficiency, and make upper limb strikes or lower limb kicks more concentrated and aggressive (Rodríguez-Perea et

al., 2023). Brown et al. found that after 6 weeks of core training, professional boxers' rear hand punch power increased by approximately 18%, significantly higher than the control group (Brown, 2021). Similarly, Kamal et al.'s study indicated that core training can significantly improve rotational stability and kicking speed in karate athletes (Kamal, 2015). These findings suggest that core training effectively enhances explosive action performance by strengthening deep stabilizing muscle groups (such as the transversus abdominis and multifidus), thereby improving body force chain synergy. Additionally, methods such as plyometric training, functional training, velocity-based resistance training, and blood flow restriction training also hold application potential in combat sports projects, providing flexible individualized schemes for athletes of varying levels.

Although this study integrated multiple high-quality randomized controlled trials through meta-analysis, it still has certain limitations. First, this article did not provide specific training prescription parameters, such as sets, repetitions, load intensity, rest time, and training frequency. These variables are important factors influencing training effects, with substantial differences and inconsistent reporting across studies, which prevented this study from further quantitatively comparing the specific impacts of different training parameters on strength and explosive power. Second, some included studies had small sample sizes, short intervention periods, and lacked follow-up observations on long-term training effects, potentially affecting the stability and generalizability of the results. Additionally, most included literature did not uniformly address potential confounding factors such as dietary control, training experience, and gender differences, which may introduce some bias to the analysis results. Future studies should detail the specific parameters of training programs in reports, adopt standardized intervention designs and data reporting formats (such as the TIDieR template), to enable higher-quality quantitative comparisons and prescriptive analyses.

From a practical perspective, the results of this study provide important guiding value for physical training in combat sports. First, training modes should be selected based on event characteristics: ground-based combat events are recommended to emphasize high-load traditional or complex training to develop maximum strength and muscular endurance; stand-up combat events should prioritize core strength and plyometric training to enhance movement rate and explosive power. Second, training plans should adhere to the principles of "individualization" and "periodization," alternating different methods across various training phases to achieve synergistic development of strength and explosive power. For example, traditional resistance and functional training can be employed in the base period to solidify the strength foundation; complex and core training introduced in the specific preparation period to

strengthen neural activation; and VBRT or BFR appropriately used in the pre-competition period for maintenance and restorative stimulation. Furthermore, the integration of strength training with sport-specific technical training should be emphasized, improving the transfer effect of strength through a "strength-technical integration" design.

5. Conclusion

This study systematically compared the effects of different strength training methods on muscle strength and explosive power in combat sports athletes. Overall, strength training can effectively promote the enhancement of physical fitness and specialized abilities in combat athletes. During training, appropriate methods should be selected based on the characteristics and objectives of the event: ground-based combat events can emphasize high-load and complex training, while stand-up combat events should prioritize core and plyometric training. Future research should further optimize training parameters, extend intervention periods, and integrate neurophysiological indicators to explore the mechanisms of strength training, thereby providing more scientific guidance for physical training in combat sports events.

6. Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

7. Author contributions

The design of the article and the collection of data were done by WF and JX. All versions of revisions were completed by YL and MFY.

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9. Data availability

The complete electronic search strategies for all databases and the detailed screening documentation are available in the Supplementary Materials.

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