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Evaluation of Cognitive Performance in Shooting Sports: A Systematic Review

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ABSTRACT

This systematic review aimed to examine studies evaluating cognitive performance in shooting sports, determine the relationship between cognitive and neurocognitive processes and shooting performance, and assess the methodological characteristics of the existing literature. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines. English-language studies published between 2015 and 2026 were searched in PubMed, Scopus, and Web of Science. Eligibility was assessed using the Participants, Intervention, Comparison, Outcomes, and Study Design framework, and original empirical studies involving sport shooters and either objective cognitive or neurocognitive measures or an explicitly defined experimental cognitive manipulation were included. A total of 261 records were identified. After removal of 101 duplicates, 160 records were screened by title and abstract, 134 were excluded, and 26 full-text articles were assessed. Following full-text screening, 16 studies were included, of which 14 directly assessed shooting performance. The studies examined attention, reaction time, processing speed, executive functions, cognitive load, mental fatigue, and neurophysiological self-regulation. The direction and consistency of effects varied across studies: seven showed favorable or preliminary favorable effects, eight showed mixed, null, or primarily associational findings, and one demonstrated an adverse effect of experimentally induced mental fatigue on shooting performance. Sport-specific visuomotor training and electroencephalography-based neurofeedback showed the most consistent pattern of concurrent cognitive or neurophysiological and shooting-performance improvements. Overall, cognitive performance appears to be an important component of shooting-sport performance, although the relationship is influenced by task specificity, psychophysiological state, and methodological characteristics.

Keywords: Shooting sports; Cognitive performance; Systematic review; Executive functions; Neurocognition

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INTRODUCTION

Sports performance is influenced not only by physical capacity and technical skills but also by cognitive processes that enable environmental information to be perceived, processed, and transformed into appropriate motor responses. In particular, high-level athletic performance requires the simultaneous and effective integration of processes such as attention, information-processing speed, cognitive control, and decision-making with motor skills. Meta-analytic studies on sport expertise have shown that experienced and elite athletes may demonstrate advantages over lower-level athletes or non-athletes in certain perceptual-cognitive tasks (Mann et al., 2007; Voss et al., 2010; Scharfen & Memmert, 2019).

Two complementary approaches are commonly used to assess cognitive performance in athletes. The expert-performance approach evaluates perceptual-cognitive skills within sport-specific tasks with high ecological validity, whereas the cognitive-component approach examines functions such as attention, information processing, working memory, and inhibition through standardized laboratory tests (Mann et al., 2007; Voss et al., 2010; Scharfen & Memmert, 2019; Manci et al., 2025; Düşkün & Ülgen, 2026). Manci et al. (2025) highlighted substantial differences in cognitive tests and administration procedures across athlete studies, noting that this heterogeneity may limit direct comparisons. These approaches are particularly relevant to shooting sports, which require accuracy, precise motor control, and sustained regulation of attention. Athletes in archery, rifle, pistol, skeet, and related disciplines must select and process visual information while coordinating highly precise motor responses. However, the demands are not uniform across disciplines. Dynamic-target events such as trap, skeet, and practical shooting require rapid target acquisition, visual tracking, response selection, and movement planning, whereas static-target events such as 10-m rifle or pistol and target archery place greater emphasis on sustained attentional control, postural stability, and fine psychophysiological regulation. Empirical findings illustrate these task-specific demands. Guo et al. (2024) reported that visual attention, target capture, perception span, hand-eye coordination, and response inhibition were associated with performance in elite skeet shooters, and that sport-specific visual training improved both visuomotor abilities and shooting accuracy. Biggs et al. (2023), using national-level practical-shooting competition data, found that expert shooters were generally faster and more accurate, while errors involving unintended targets were also related to planning demands beyond basic shooting skill.

In recent years, research has increasingly focused not only on describing cognitive performance in shooting sports but also on enhancing it through various interventions. Guo et al. (2024)

reported positive changes in shooting performance following sport-specific visuomotor training in elite skeet shooters. Similarly, Chen et al. (2025) reported beneficial effects of sensorimotor rhythm-based electroencephalographic neurofeedback in professional shooters, while Lo et al. (2025) observed improvements associated with temporal alpha neurofeedback in pre-elite air-pistol shooters. Across these studies, improvements in shooting performance were accompanied by changes in cognitive or neurophysiological outcomes. However, changes in cognitive state do not invariably result in improved performance. Soylu et al. (2026) demonstrated that acute mental fatigue significantly reduced shooting scores in well-trained compound archers, whereas mean heart rate did not differ substantially between conditions. This finding suggests that precision shooting performance may be affected by cognitive state independently of physical load. Existing studies examining cognitive performance in shooting sports encompass different disciplines, athlete levels, cognitive tests, neurophysiological assessment methods, and intervention approaches. Although this diversity contributes to the development of the field, it complicates interpretation of the overall relationship between cognitive performance and shooting performance. Therefore, systematically synthesizing research specifically conducted in shooting sports is important for identifying the cognitive domains that have been investigated, determining how these domains have been related to shooting performance, and evaluating the methodological characteristics of the available evidence.

The aim of this systematic review was to systematically examine the available studies evaluating cognitive performance in shooting sports, identify the cognitive and neurocognitive assessment methods used, evaluate the relationships of processes such as attention, reaction time, executive functions, cognitive load, and neurophysiological self-regulation with sport-shooting performance, and characterize the methodological features of the existing literature.

MATERIAL and METHODS

Search Strategy and Study Selection

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines (Page et al., 2021). The literature search was performed in PubMed, Scopus, and Web of Science electronic databases.

In accordance with the scope of the review, the terms “shooting,” “shooting sport,” “shooting athletes,” “archery,” and “marksmanship” were used to represent shooting sports, while “cognitive performance,” “cognition,” “cognitive tests,” “reaction time,” and “attention” were used to represent cognitive performance. Searches were limited to English-language articles

published between 2015 and 2026, and the final search was updated in August 2026. The documented search concepts were adapted to the field tags and syntax requirements of each database and combined using the Boolean operators AND and OR.

The database-adapted search strings were as follows:

> **PubMed:** ("shooting" OR "shooting sport" OR "shooting athletes" OR "archery" OR "marksmanship") AND ("cognitive performance" OR "cognition" OR "cognitive tests" OR "reaction time" OR "attention")
>
> **Scopus:** TITLE-ABS-KEY(("shooting" OR "shooting sport" OR "shooting athletes" OR "archery" OR "marksmanship") AND ("cognitive performance" OR "cognition" OR "cognitive tests" OR "reaction time" OR "attention"))
>
> **Web of Science:** TS=(("shooting" OR "shooting sport" OR "shooting athletes" OR "archery" OR "marksmanship") AND ("cognitive performance" OR "cognition" OR "cognitive tests" OR "reaction time" OR "attention"))

The retrieved records were combined using reference-management software, duplicate records were removed, and studies were screened first at the title and abstract level and subsequently at the full-text level according to predefined eligibility criteria.

Title and abstract screening, full-text eligibility assessment, data extraction, and methodological quality appraisal were conducted by the author.

Eligibility Criteria

Eligibility criteria were developed using the Participants, Intervention, Comparison, Outcomes, and Study Design (PICOS) framework (Harris et al., 2014).

Participants

Studies examining athletes actively participating in shooting sports were included. Eligible samples comprised elite, pre-elite, national-level, youth, or novice athletes participating in archery, sport rifle and pistol shooting, air rifle and air pistol, skeet, biathlon, the shooting component of modern pentathlon, and practical sport shooting. General volunteers who were not identified as sport shooters, participants who performed virtual or real shooting tasks only for research purposes, and military or police samples involved in operational contexts were excluded.

Intervention or Exposure

Studies investigating acute or chronic cognitive, psychological, neurophysiological, behavioral, nutritional or supplementation-based, and training-based interventions were eligible. Observational studies assessing cognitive processes in shooting-sport athletes were also included.

Comparison

No specific comparator was required. Eligible studies included placebo or sham controls, active controls, normal or control conditions, within-subject comparisons, and observational designs comparing different performance or expertise groups.

Outcomes

For inclusion, studies were required to assess cognitive performance using an objective or directly measurable cognitive or neurocognitive outcome, or to employ an explicitly defined experimental cognitive manipulation such as cognitive load or mental fatigue. Eligible outcomes included attention, reaction time, processing speed, executive function, inhibition, working memory, cognitive flexibility, decision-making, cognitive load, mental fatigue, and electroencephalography- or functional near-infrared spectroscopy-based neurocognitive indicators. Studies relying solely on self-report measures of psychological state without an objective cognitive or neurocognitive measure or a clearly defined cognitive manipulation were excluded. Direct measurement of shooting performance was preferred but was not required for inclusion.

Study Design

Original empirical studies involving human participants and available in full text were eligible. Randomized controlled trials, crossover designs, quasi-experimental intervention studies, and analytical observational studies were included. Reviews, meta-analyses, conference abstracts, animal studies, and publications not reporting original data were excluded.

Data Extraction

The full texts of the included studies were reviewed using a standardized data-extraction form. For each study, the following information was systematically recorded: author and year of publication, country or research setting, shooting discipline, sample size and participant characteristics, athlete level, study design, intervention or exposure, comparator, intervention duration, cognitive or neurocognitive measures, shooting or performance measures, main cognitive findings, main shooting findings, and methodological limitations.

Methodological Quality Assessment

The methodological quality of the included studies was assessed using Joanna Briggs Institute critical appraisal tools appropriate to each study design. Randomized controlled trials were evaluated using the JBI Critical Appraisal Checklist for Randomized Controlled Trials, non-randomized intervention and within-subject studies using the JBI Critical Appraisal

Checklist for Quasi-Experimental Studies, and analytical observational studies using the JBI Critical Appraisal Checklist for Analytical Cross-Sectional Studies (Barker et al., 2023; Barker et al., 2024; Moola et al., 2020). Each item was rated as Yes, No, Unclear, or Not Applicable. No automatic inclusion or exclusion threshold based on a total score was applied. The appraisal was used to support interpretation of the findings.

Data Synthesis

Because the included studies showed substantial heterogeneity in shooting discipline, sample characteristics, study design, intervention type, and cognitive assessment methods, the findings were synthesized narratively. Results were grouped into thematic categories including attention and processing speed, neurofeedback and neural efficiency, executive function and cognitive load, mental state, fatigue and sleep, and mind-body and behavioral interventions.

RESULTS

Study Selection

A total of 261 records were identified through searches of PubMed, Scopus, and Web of Science. Of these, 64 records were retrieved from PubMed, 149 from Scopus, and 48 from Web of Science. After the removal of 101 duplicate records, 160 records were screened by title and abstract. At this stage, 134 records were excluded because they clearly failed to meet one or more predefined criteria; these records involved non-sport shooting contexts, ineligible populations, absence of an objective cognitive or neurocognitive outcome or an explicit cognitive manipulation, non-original publication types, or topics unrelated to shooting-sport performance. This left 26 articles for full-text assessment. Following full-text evaluation, 10 studies were excluded: six because the samples did not consist of sport shooters, two because they involved military or police operational samples, and two because they did not include an appropriate objective cognitive-performance outcome. Consequently, 16 studies were included in the systematic review. The study selection process is presented in Figure 1.

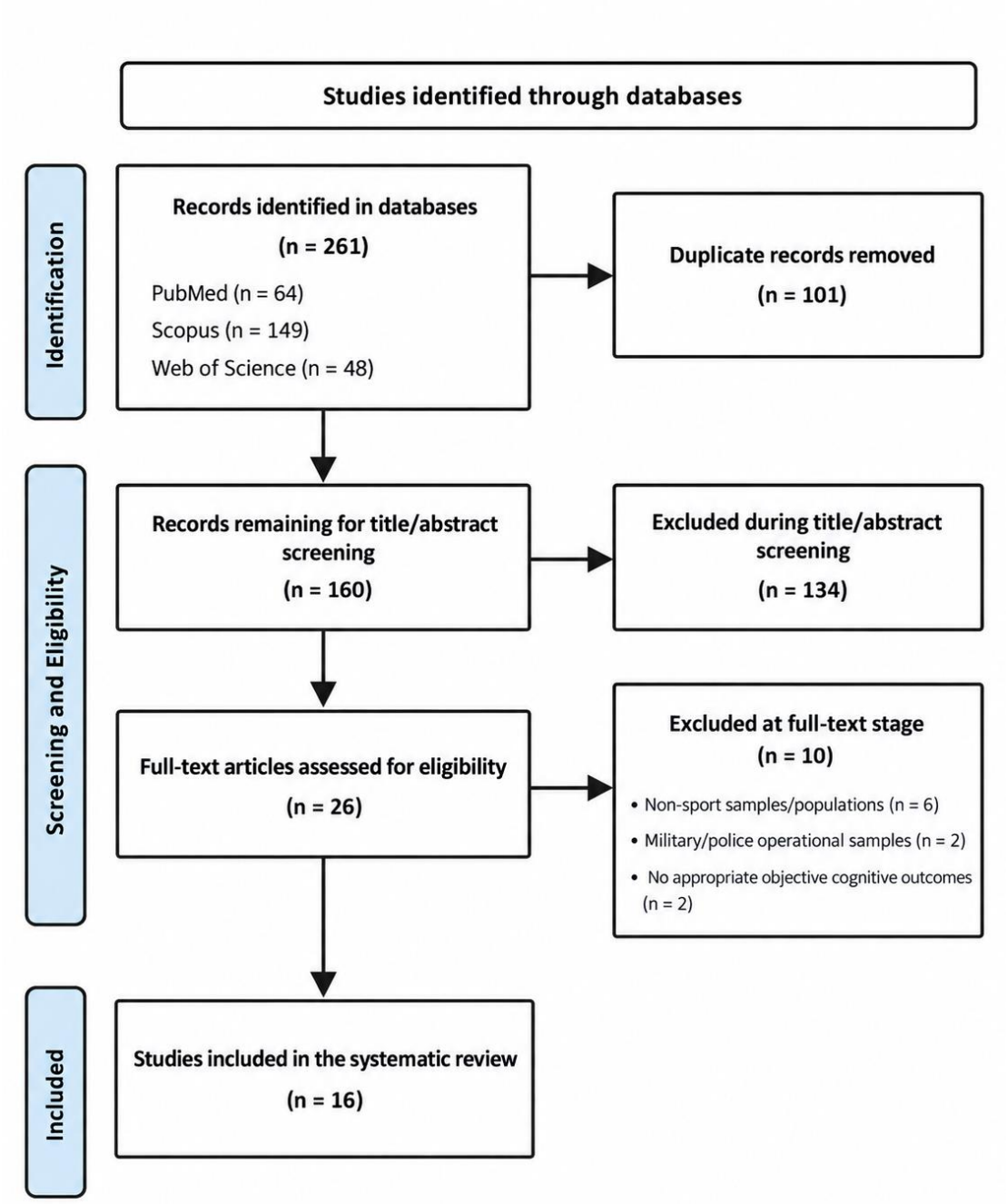


Figure 1: PRISMA 2020 flow diagram of the study selection process.

Characteristics of the Included Studies

The studies included in the review were published between 2016 and 2026 and covered several shooting disciplines, including archery, air rifle and air pistol, sport rifle and pistol shooting, skeet, biathlon, modern pentathlon, and practical shooting. Five studies involved archery, eight involved sport rifle, pistol, air-weapon, or practical-shooting athletes, one involved skeet shooters, one study involved biathlon athletes, and one involved modern pentathletes. Direct shooting performance was assessed in 14 studies (Leichtfried et al., 2016;

Suppiah et al., 2016; Pomportes et al., 2019; Hung et al., 2021; Biggs et al., 2023; Feng, 2023; Bartura et al., 2024; Guo et al., 2024; Chen et al., 2025; Keskin & Tunalı Van Den Berg, 2025; Lo et al., 2025; Buzdağlı et al., 2026; Cheng et al., 2026; Soylu et al., 2026); Xiang et al. (2023) and Baishya et al. (2025) did not include a direct shooting-performance outcome. Cognitive assessments covered attention, reaction time, processing speed, response inhibition, working memory, cognitive flexibility, mental fatigue, and planning, while some studies also used neurophysiological methods such as electroencephalography and functional near-infrared spectroscopy. Participant characteristics, study designs, cognitive and neurocognitive assessments, intervention or exposure methods, additional measures, shooting outcomes, key findings, and major limitations are presented chronologically in Table 1.

Table 1: Characteristics of Participants, Cognitive/Neurocognitive Assessment Methods, Shooting Measures, and Main Findings of the Included Studies

Author (Year)	Participants / discipline / level	Design and intervention / exposure	Cognitive / neurocognitive test and domain	Testing method / platform / familiarization	Other measures	Shooting / performance measure	Key findings	Main limitation	Country / setting
Leichtfried et al. (2016)	n=15 rifle/pistol shooters; mixed competitive sample.	Crossover; 30 min of 5000 lux bright light vs. <150 lux dim light; 7-day interval.	Sustained attention and choice reaction time.	Vienna Test System-based computerized assessment; condition order/randomization and familiarization details limited.	Biochemical/psychophysiological measures.	40-shot performance score.	Attention accuracy improved under bright light; reaction time and shooting score did not change significantly.	Small sample; order effects and previous sleep/external light exposure not fully controlled.	Austria
Suppiah et al. (2016)	n=24 high-level adolescent rifle/pistol shooters.	Natural repeated-measures comparison of restricted school-term sleep vs. less restricted holiday sleep.	Psychomotor Vigilance Task; 1-back and 2-back working memory.	Computerized cognitive tasks; same athletes followed across school and holiday periods; platform/familiarization details limited.	Total sleep duration and sleep characteristics.	ISSF/SCATT-based shooting measures.	No clear cognitive or direct shooting difference between conditions; sleep duration was associated with selected performance indicators.	Not randomized/counterbalanced; school-holiday calendar effects are an important confounder.	Singapore
Pomportes et al. (2019)	n=10 international-level modern pentathletes.	Single-blind four-condition crossover: carbohydrate, caffeine, guarana, or placebo plus 40 min running.	Simon task; reaction time and inhibition/incongruency effect.	Computerized Simon task; single-blind, pseudo-counterbalanced order; familiarization/platform details limited.	Perceived exertion and exercise-related physiological indicators.	Pistol shooting after running.	Some cognitive response measures improved; supplements did not reliably prevent the exercise-related decline in shooting performance.	Very small sample; acute conditions and possible order/carryover effects.	France
Hung et al. (2021)	n=11 men; national-level recurve archers.	Randomized placebo-controlled crossover; 2 mg nicotine vs. placebo.	Cognitrone; Grooved Pegboard; motor reaction time.	Standardized cognitive/fine-motor tasks under crossover conditions; randomization, concealment, blinding, and familiarization incompletely reported.	Fine-motor coordination indicators.	72-arrow simulated competition score.	Correct-rejection time and pegboard performance improved; shooting score was higher with nicotine (298.05 ± 8.56 vs. 290.58 ± 10.09; p = .009).	n=11, men only; acute intervention; some methodological details unclear.	Taiwan
Biggs et al. (2023)	Sport Experiment 1: 332 USPSA Production Nationals competitors; complete data n=323.	Archival analytical observational design examining expertise, stage structure, and planning opportunity; military Experiment 2 excluded.	No-shoot errors, planning demands, and speed-accuracy patterns used as cognitive-performance indicators instead of a laboratory test.	Real competition data; familiarization not applicable; cognitive measurement derived from competitive behavior.	Stage characteristics, speed, and accuracy metrics.	USPSA national competition performance and no-shoot hits.	Experts were generally faster/more accurate; cognitive errors were not explained solely by basic shooting skill and were related to planning conditions.	Observational design; stages were not matched; no causal inference.	United States

Author (Year)	Participants / discipline / level	Design and intervention / exposure	Cognitive / neurocognitive test and domain	Testing method / platform / familiarization	Other measures	Shooting / performance measure	Key findings	Main limitation	Country / setting
Feng (2023)	Traditional male archers; abstract reports n=20, methods n=30.	Analytical cross-sectional comparison of performance groups defined by shooting success.	Concentration and relaxation indices.	Single-channel NeuroSky EEG; familiarization and measurement standardization poorly reported.	EEG-based attention/relaxation indicators.	Ring value / 10-ring success.	Relaxation index was higher for higher-scoring shots; concentration relationship was less consistent.	Inconsistent sample size; single-channel EEG; weak selection criteria and confounder control.	China
Xiang et al. (2023)	n=33 adolescent shooting athletes; combined training n=17, cognitive training n=16.	Randomized active-controlled; 6 weeks of combined physical+cognitive training vs. cognitive training.	2-back working memory; task switching; Stroop inhibition; fNIRS cortical response.	Computerized executive-function tasks with fNIRS; randomization/concealment/blinding and familiarization details limited.	fNIRS hemodynamic measures.	No direct shooting-performance measure.	2-back performance improved in both groups; task switching improved clearly only in the combined group; Stroop change was limited.	Small sample; no direct shooting outcome; limited randomization/blinding reporting.	China
Bartura et al. (2024)	Semi-elite biathletes; Experiment 1 n=10, Experiment 2 n=9.	Two within-participant experiments with low/high cognitive load and different cue conditions.	Reverse-Stroop-based cognitive load; response time and error indicators.	Cognitive load integrated with shooting task; condition order not fully counterbalanced; platform/familiarization details limited.	Manipulation checks and cognitive-load indicators.	Biathlon rifle target accuracy.	Shooting accuracy was largely preserved across conditions; selected response-time measures slowed under high cognitive load.	Very small samples; order effects; cognitive-load manipulation only partly successful.	Norway
Guo et al. (2024)	n=20 elite skeet shooters; 10 training, 10 active control.	Randomized active control; 6-week sport-specific visual/visuomotor training vs. workload-matched tracking task.	Perceptual span; target capture; hand-eye coordination; Go/No-Go/response inhibition; reaction time.	Sport-specific visuomotor training battery; workload matched in active control; randomization/blinding and familiarization details limited.	Multiple visuomotor performance indicators.	Skeet hits and gun-raising reaction time.	Most visuomotor measures improved; skeet accuracy increased from 50.8 to 54.3 in the training group ($p = .003$).	Small elite sample; ceiling effects in some measures and limited blinding.	China
Baishya et al. (2025)	14 elite archers; 13 completed.	Single-group pre-post design; 2-week yoga module.	Stroop test; reaction time and accuracy.	Standard pre-post Stroop assessment; no control group; limited platform and familiarization details.	CSAI-2R, balance, and psychological indicators.	No direct shooting-performance measure.	Stroop reaction time decreased and accuracy increased; positive preliminary psychological/balance findings.	No control group; 13/14 analyzed; 2-week pilot; possible retest and expectancy effects.	India

Author (Year)	Participants / discipline / level	Design and intervention / exposure	Cognitive / neurocognitive test and domain	Testing method / platform / familiarization	Other measures	Shooting / performance measure	Key findings	Main limitation	Country / setting
Chen et al. (2025)	n=30 professional shooters; 15 real neurofeedback, 15 sham.	Randomized sham-controlled; 4-week sensorimotor-rhythm EEG neurofeedback plus follow-up.	Simple and choice reaction time; EEG/SMR; COSMI neurocognitive indicators.	EEG-based real vs. sham neurofeedback; computerized reaction-time tasks; randomization/concealment and blinding partly unclear.	EEG/COSMI neurophysiological indicators.	Shooting accuracy and variability/consistency.	Simple reaction time decreased from 230 ± 25 to 210 ± 20 ms, and choice reaction time decreased from 350 ± 35 to 305 ± 30 ms; SMR increased by approximately 37%; accuracy increased from 9.2 ± 0.5 to 9.7 ± 0.4 and variability decreased from 0.8 ± 0.2 to 0.5 ± 0.1.	n=30; insufficient reporting of randomization/allocation concealment and some blinding procedures.	China
Keskin & Tunalı Van Den Berg (2025)	n=21 novice archers; breathing/imagery/control groups 7/7/7.	Randomized pilot; 8 weeks of breathing exercise or imagery practice.	Bourdon attention test; visual reaction time; imagery measure.	Standard attention and visual reaction-time assessment; additional contact time in intervention groups; no blinding/placebo or familiarization details.	Postural sway and imagery indicators.	Target score.	Attention and reaction time improved; target score rose ~18.8→25.8 in breathing and 14.8→25.0 in imagery groups.	n=7/group; no blinding/placebo; intervention attention/contact time unequal across groups.	Turkey
Lo et al. (2025)	n=20 pre-elite air-pistol shooters; neurofeedback n=10, control n=10.	Randomized controlled; 16 sessions of left temporal (T3) alpha neurofeedback over 5-6 weeks.	Temporal alpha power/coherence and ability to sustain alpha activity.	T3 EEG neurofeedback with EEG recordings and a 40-shot test; no sham or participant/provider blinding; limited familiarization details.	EEG alpha power and coherence.	40-shot precision pistol score.	Score increased 365.9→376.0 in neurofeedback and decreased 369.8→367.1 in control; group×time $p < .001$; T3 alpha-hold duration correlated with score ($r = .89$).	n=10/group; no sham; limited blinding; possible baseline age imbalance.	Taiwan
Buzdağlı et al. (2026)	n=15 elite young women, 10-m air-rifle shooters.	Randomized double-blind placebo-controlled crossover; L-theanine, L-arginine, combination, placebo; 72-h washout.	d2 attention test; Stroop test.	Standardized testing time; independent randomization/coding, identical opaque capsules, assessor blinding, 72-h washout.	Supplement conditions and cognitive-performance indicators.	ISSF 60-shot score.	L-theanine and especially the combination improved attention/Stroop performance; shooting score 614.0 with placebo vs. 631.4 with combination ($p < .001$).	Small women-only sample; acute supplementation; limited generalizability.	Turkey
Cheng et al. (2026)	n=35 male IPSC Class B competitors.	Within-participant Latin-square design; reward, punishment, and neutral monetary-motivation conditions.	EEG: fERN, theta, SMR; performance monitoring and neurocognitive control.	Motivation conditions Latin-square counterbalanced; EEG and HRV recorded concurrently during simulated shooting; familiarization details limited.	HRV and autonomic indicators.	Simulated IPSC shooting performance.	Reward and punishment conditions altered EEG and autonomic (HRV) indicators; effects on shooting performance were not unidirectional.	Acute simulated design; no long-term follow-up; men only.	China

Author (Year)	Participants / discipline / level	Design and intervention / exposure	Cognitive / neurocognitive test and domain	Testing method / platform / familiarization	Other measures	Shooting / performance measure	Key findings	Main limitation	Country / setting
Soylu et al. (2026)	n=15 men, well-trained compound archers.	Randomized counterbalanced crossover; 30-min modified Stroop mental-fatigue condition vs. documentary control; 72-h washout.	Modified Stroop mental-fatigue induction; subjective mental fatigue/effort indicators.	Condition order counterbalanced; 72-h washout; Stroop used primarily to induce fatigue; participant blinding impossible.	RSME, RPE, mood state, and heart rate.	72-arrow / 50-m simulated competition score.	Mental fatigue and perceived exertion increased; shooting score decreased to 606.71 vs. 619.62 in control ($p = .015$; $g = -.73$).	n=15, men only; blinding impossible; simulated competition setting.	Turkey

Note. COSMI = cognitive sensorimotor integration; CSAI-2R = Revised Competitive State Anxiety Inventory-2; EEG = electroencephalography; fNIRS = functional near-infrared spectroscopy; HRV = heart-rate variability; IPSC = International Practical Shooting Confederation; ISSF = International Shooting Sport Federation; RPE = rating of perceived exertion; RSME = Rating Scale Mental Effort; SCATT = electronic shooting-training system; SMR = sensorimotor rhythm; USPSA = United States Practical Shooting Association.

Attention, Reaction Time, and Processing Speed

Studies focusing on attention, reaction time, and information-processing speed generally reported positive but not entirely consistent findings. Hung et al. (2021) reported that 2 mg nicotine administration in 11 national-level recurve archers improved Cognitrone correct-rejection time and Grooved Pegboard performance, while simulated competition scores were higher than under placebo (298.05 ± 8.56 vs. 290.58 ± 10.09; p = .009). Guo et al. (2024) showed that six weeks of sport-specific visual training improved several visuomotor abilities and skeet shooting accuracy in elite skeet shooters. Keskin and Tunalı Van Den Berg (2025) reported that breathing and imagery interventions were associated with positive changes in attention, visual reaction time, and target scores. Buzdağlı et al. (2026) showed that L-theanine, particularly when combined with L-arginine, improved attention and Stroop performance together with shooting scores. In contrast, despite some positive changes in cognitive measures, no significant improvement in shooting performance was observed in the studies by Pomportes et al. (2019) and Leichtfried et al. (2016). This pattern suggests that improvements in general cognitive performance do not automatically transfer to shooting performance.

Neurofeedback and Neurophysiological Performance

Chen et al. (2025) reported improvements in both simple and choice reaction time, together with increased shooting accuracy, following four weeks of sensorimotor rhythm electroencephalographic neurofeedback. Lo et al. (2025) similarly showed that temporal alpha neurofeedback increased electroencephalographic alpha power and shooting scores, and that the duration of maintaining T3 alpha activity was strongly associated with shooting performance. Although these findings suggest that neurofeedback may be promising for shooting sports, the small sample sizes limit the generalizability of the results.

Executive Function, Cognitive Load, and Planning

Xiang et al. (2023) reported that combined physical-cognitive training improved task-switching accuracy, although no significant behavioral change was observed in Stroop performance. Bartura et al. (2024) showed that semi-elite biathletes were largely able to maintain shooting accuracy under high cognitive load, although some response-time measures were affected. Biggs et al. (2023), using national USPSA competition data, reported that no-shoot errors could not be explained solely by basic shooting accuracy and that planning opportunities and stage structure were also associated with cognitive errors.

Mental Fatigue, Motivation, Sleep, and Arousal

Soylu et al. (2026) showed that experimentally induced mental fatigue adversely affected archery performance: scores were significantly lower under the mental-fatigue condition than under the control condition (606.71 ± 41.10 vs. 619.62 ± 41.10; $p = .015$; $g = -.73$). Cheng et al. (2026) reported that reward and punishment conditions altered electroencephalographic and autonomic nervous system indicators, although their effects on performance were not unidirectional. Suppiah et al. (2016) found no significant differences in psychomotor vigilance, working memory, or direct shooting performance across five-day sleep conditions; however, total sleep duration was associated with some shooting-performance indicators. Feng (2023) reported an association between higher-performing shots and relaxation indices; however, the abstract reported 20 participants whereas the Methods section reported 30, creating a sample-size inconsistency that weakens confidence in the findings.

Mind-Body and Behavioral Interventions

Keskin and Tunalı Van Den Berg (2025) and Baishya et al. (2025) showed that breathing, imagery, and yoga-based approaches may provide preliminary positive findings for attention, reaction time, and certain psychological indicators. However, particularly in the study by Baishya et al. (2025), the absence of a control group and direct shooting-performance measurement limits strong causal inference.

Methodological Quality Findings

Eight of the 16 included studies were assessed as randomized controlled trials, six as quasi-experimental studies, and two as analytical cross-sectional studies. In randomized studies, the most common uncertainties were related to inadequate reporting of random-sequence generation, allocation concealment, and blinding procedures. In quasi-experimental studies, the main methodological concerns were the absence of control groups, insufficient counterbalancing of condition order, and small sample sizes. In cross-sectional studies, the principal methodological issues involved the control of confounding variables and the clarity of measurement and sample definitions. A detailed appraisal is presented in Table 2.

Table 2: Summary of JBI Methodological Quality Assessment of the Included Studies

Study	JBI Tool	Narrative Assessment*	Main Methodological Limitation
Leichtfried et al. (2016)	JBI Quasi-Experimental	Moderate-high	n=15; limited reporting of condition order/randomization and control of external light exposure and prior sleep.

Study	JBI Tool	Narrative Assessment*	Main Methodological Limitation
Suppiah et al. (2016)	JBI Quasi-Experimental	High	Not randomized or counterbalanced; school-versus-holiday schedule was an important confounder.
Pomportes et al. (2019)	JBI Quasi-Experimental	Moderate	Pseudo-counterbalancing; 10 of 12 participants analyzed; small sample.
Hung et al. (2021)	JBI RCT	Moderate	Limited reporting of randomization, allocation concealment, blinding, and washout/carryover procedures.
Biggs et al. (2023)	JBI Analytical Cross-Sectional	Moderate-high	Stages were not matched; causal inference cannot be established.
Feng (2023)	JBI Analytical Cross-Sectional	High	Inconsistent sample size (20/30); single-channel EEG; weak control of confounders.
Xiang et al. (2023)	JBI RCT	Moderate	Limited reporting of randomization, allocation concealment, and blinding; no direct shooting outcome.
Bartura et al. (2024)	JBI Quasi-Experimental	Moderate-high	Very small sample; cognitive-load order was not counterbalanced.
Guo et al. (2024)	JBI RCT	Moderate	Limited reporting of blinding and randomization; n=20.
Baishya et al. (2025)	JBI Quasi-Experimental	High	No control group; 2-week pilot; possible retest and expectancy effects.
Chen et al. (2025)	JBI RCT	Moderate	Strong sham condition; limited reporting of randomization, allocation concealment, and blinding.
Keskin and Tunalı Van Den Berg (2025)	JBI RCT	High	n=7 per group; no blinding/placebo; intervention exposure was not equivalent across groups.
Lo et al. (2025)	JBI RCT	Moderate-high	No sham condition; limited blinding; n=20.
Buzdağlı et al. (2026)	JBI RCT	Low	Well reported; main limitation was a small, female-only sample.
Cheng et al. (2026)	JBI Quasi-Experimental	Moderate	Acute design; no long-term follow-up.
Soylu et al. (2026)	JBI RCT	Moderate	Blinding was not possible; n=15.

Note. JBI = Joanna Briggs Institute; RCT = randomized controlled trial. The narrative assessment reflects the author's interpretation and is not an official JBI category system. Item-level Yes/No/Unclear/Not Applicable judgments were retained separately in the study file.

Overall Synthesis of Findings

Across the included studies, the direction and consistency of effects on cognitive or neurophysiological outcomes and shooting performance varied. Seven studies showed favorable or preliminary favorable effects (Hung et al., 2021; Guo et al., 2024; Baishya et al., 2025; Chen et al., 2025; Keskin & Tunalı Van Den Berg, 2025; Lo et al., 2025; Buzdağlı et al., 2026). Eight studies showed mixed, predominantly null, or primarily associational findings (Leichtfried et al., 2016; Suppiah et al., 2016; Pomportes et al., 2019; Biggs et al., 2023; Feng,

2023; Xiang et al., 2023; Bartura et al., 2024; Cheng et al., 2026). One study demonstrated an adverse effect of an experimentally induced state: mental fatigue reduced shooting performance (Soylu et al., 2026). These categories describe the observed direction and consistency of effects rather than labeling entire studies as positive or negative. Overall, attention, reaction time, and neurophysiological self-regulation appear relevant to shooting performance, but improvements in general cognitive tests do not consistently transfer to direct improvements in shooting scores.

DISCUSSION

General Evaluation

The primary aim of this systematic review was to examine how cognitive performance has been assessed in shooting sports and to evaluate the relationship between cognitive processes and sport-shooting performance. The findings from the 16 included studies indicate that factors such as attention, reaction time, executive functions, cognitive load, mental fatigue, and neurophysiological self-regulation are associated with shooting performance. However, improvements in cognitive performance did not consistently translate into higher shooting performance. This finding highlights the importance of considering the specificity of the relationship between cognitive processes and the sporting task. In sport science, the distinction between standardized cognitive tasks and sport-specific tasks with high ecological validity has also been emphasized previously (Mann et al., 2007; Scharfen & Memmert, 2019; Manci et al., 2025).

Attention, Reaction Time, and Task-Specific Transfer

In the present review, improvements in cognitive performance were accompanied by improvements in shooting performance in the studies by Hung et al. (2021), Guo et al. (2024), Keskin and Tunalı Van Den Berg (2025), and Buzdağlı et al. (2026). In contrast, Pomportes et al. (2019) and Leichtfried et al. (2016) reported positive changes in some cognitive measures without significant improvements in shooting performance. This difference suggests that gains in general cognitive performance may not automatically transfer to sport-specific performance. Mann et al. (2007) similarly reported that expertise-related advantages are influenced by the sport specificity of the task used.

Neurofeedback and Neural Self-Regulation

In the present review, studies examining neurofeedback interventions, including Chen et al. (2025) and Lo et al. (2025), reported positive findings in both neurophysiological indicators and sport-shooting performance. These results are consistent with the broader sport

neurofeedback literature. In a systematic review and meta-analysis, Yu et al. (2025) reported a moderate positive effect of electroencephalographic neurofeedback on sport motor performance (Hedges' g = 0.78; 95% confidence interval: 0.49–1.07). However, the available shooting studies included small samples and used different control procedures; therefore, larger sham-controlled studies with long-term follow-up are needed. The time course and likely mechanisms of the reviewed interventions should also be distinguished. Acute manipulations, including single-dose supplementation or nicotine and a single mental-fatigue induction, primarily reflect short-term fluctuations in arousal, attention, perceived effort, or performance. By contrast, four- to six-week neurofeedback and visuomotor-training programs may involve repeated skill learning and longer-term neuroplastic adaptation. These intervention classes should therefore not be interpreted as equivalent, and future studies should include retention assessments to determine whether apparent gains persist beyond the immediate testing period.

Executive Functions, Planning, and Cognitive Load

The findings reported by Xiang et al. (2023), Bartura et al. (2024), and Biggs et al. (2023) highlight the importance of executive functions such as working memory, task switching, inhibition, and planning in shooting performance. In particular, Biggs et al. (2023) showed that no-shoot errors could not be explained solely by shooting accuracy and that planning conditions were associated with performance. Future research may therefore benefit from using tasks that integrate inhibition, cognitive flexibility, and planning directly into shooting scenarios alongside general attention tests.

Mental Fatigue and Shooting Performance

The clearest adverse effect of an experimentally induced cognitive state was reported by Soylu et al. (2026), in whom mental fatigue reduced shooting performance relative to the control condition. This result should not be interpreted as a "negative study"; rather, it provides evidence that an adverse cognitive state can impair performance. Mean heart rate did not change substantially, suggesting that the decrement may have been related more closely to cognitive or perceptual load than to physical fatigue. This finding is consistent with evidence from other sports. Ding et al. (2024) reported that mental fatigue in racket sports may reduce the accuracy and speed of technical skills, prolong psychomotor response times, and increase perceived exertion.

Motivation, Arousal, and Psychophysiological State

Cheng et al. (2026) showed that reward and punishment conditions altered electroencephalographic and autonomic nervous system indicators in shooters, although the effects on performance were not unidirectional. Feng (2023) reported that higher-performing shots may, under some conditions, be associated with higher relaxation indices. These findings suggest that greater arousal does not necessarily correspond to better shooting performance and that regulation of an appropriate task-specific psychophysiological state may be more important.

Mind-Body Interventions

Keskin and Tunalı Van Den Berg (2025) and Baishya et al. (2025) reported preliminary positive findings for breathing, imagery, and yoga-based interventions. The broader sport literature shows a similar pattern. In a systematic review and meta-analysis of 32 randomized controlled trials, Wang et al. (2023) reported that mindfulness-based interventions may have beneficial effects on sport performance and mindfulness-related psychological variables, while also emphasizing the need for higher-quality randomized controlled trials.

Methodological Heterogeneity and Interpretation of Evidence

An important finding of this systematic review is the substantial heterogeneity across studies in sample characteristics, research design, cognitive assessment methods, and shooting-performance measures. This issue is not unique to shooting sports. Manci et al. (2025) reported considerable heterogeneity in the methodological procedures used to assess cognitive performance in athletes and emphasized the need for more standardized procedures for administering and reporting cognitive tests. The present JBI appraisal similarly indicated that limitations related to randomization, allocation concealment, blinding, small samples, and counterbalancing reduced the strength of interpretation. The main methodological limitations identified in this review and recommendations for future research are summarized in Table 3.

Table 3: Main Methodological Limitations in the Cognitive-Performance Literature on Shooting Sports and Recommendations for Future Research

Main Limitation in the Current Literature	Recommendation for Future Research
Samples are generally small and heterogeneous in discipline, age, sex, and athlete level.	Use larger samples supported by a priori power analyses; where possible, employ multicenter designs and report results by discipline, sex, and athlete level.
Random-sequence generation, allocation concealment, and blinding are inadequately or ambiguously reported in many studies.	Randomized studies should report randomization, concealment, and blinding procedures in detail and, where possible, use sham or workload-matched active control conditions.

Main Limitation in the Current Literature	Recommendation for Future Research
Versions and platforms of cognitive tests, screen or environmental characteristics, administration order, and familiarization procedures are not standardized across studies.	Report the test name and version, software and hardware, screen characteristics, participant-to-screen distance, administration order, number of trials or familiarization procedures, and environmental conditions in a standardized manner.
Improvements in general cognitive tests do not always transfer to shooting performance.	Combine laboratory-based cognitive measures with sport-specific, ecologically valid tasks and direct measures of shooting performance.
Some studies do not include direct shooting outcomes or rely on simulated shooting protocols.	Where possible, use standardized live-shooting protocols and competition-like conditions, and cross-validate simulator outcomes against live-shooting performance.
Many interventions are acute or short-term, with limited follow-up or retention assessment.	Use longer-term interventions, delayed follow-up assessments, and designs that evaluate the retention of learning or performance gains.
High heterogeneity across cognitive domains, tests, and performance outcomes limits quantitative synthesis.	Develop core cognitive outcome sets for shooting sports so that reaction time, accuracy, inhibition, attention, and direct shooting performance are reported using common measures.

Note. The recommendations synthesize recurring methodological limitations identified across the included studies and indicate priorities for future research; they are not formal JBI requirements.

Practical Applications

The available evidence suggests that cognitive preparation in shooting sports should extend beyond general concentration exercises. Laboratory tests such as the Stroop task, Psychomotor Vigilance Task, and Cognitrone isolate specific functions under controlled conditions, whereas performance on the range is simultaneously affected by time pressure, changing wind and light, competitive anxiety, target motion, and tactical demands. Coaches may therefore combine standardized cognitive assessments with ecologically valid dual-task drills, for example requiring target engagement while athletes respond to changing visual cues, inhibit no-shoot targets, make rapid planning decisions, or maintain technique under controlled time pressure. Training programs may benefit from integrating visuomotor attention, target selection, inhibition, planning, and psychophysiological self-regulation skills that closely resemble the demands of the specific shooting discipline.

Limitations

The interpretation of the present review is limited by substantial heterogeneity in shooting disciplines, athlete characteristics, study designs, cognitive measures, and shooting protocols. Many included studies used small samples, short-term interventions, or incompletely reported randomization, concealment, blinding, and counterbalancing procedures, and two studies did not include direct shooting-performance outcomes. In addition, the search was limited to English-language journal articles and excluded grey literature such as theses and

conference proceedings; consequently, publication and language bias cannot be ruled out. The review protocol was not prospectively registered, which limits the ability to verify that all planned methods were specified in advance. Finally, screening, extraction, and appraisal were performed by a single author rather than being completed independently in duplicate, which may increase the risk of selection or extraction error. Future research should use larger and more homogeneous athlete samples, standardized live-shooting measures, clearly reported methodological procedures, appropriate sham or active control conditions where feasible, and longer-term follow-up to determine the persistence of intervention effects.

CONCLUSION

This systematic review synthesized 16 studies examining cognitive performance in shooting sports and indicates that attention, reaction time, executive functions, cognitive load, mental fatigue, and neurophysiological self-regulation are relevant to sport-shooting performance. Direct shooting performance was assessed in 14 studies, but improvements in cognitive measures did not consistently translate into better shooting outcomes. Sport-specific visuomotor training and electroencephalographic neurofeedback showed the most consistent pattern of concurrent cognitive or neurophysiological improvement and enhanced shooting performance, whereas mental fatigue emerged as a factor that may impair performance. Given the methodological heterogeneity of the available evidence, larger and better-controlled studies using standardized, sport-specific cognitive and live-shooting assessments are needed before any single cognitive intervention can be recommended as a standard performance-enhancement method across shooting disciplines.

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