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Cognitive performance determinants in competitive fencing: a systematic review

Ade Zalindro*), Rudyanto Rudyanto, M. Arie Desman
Universitas Negeri Padang, Indonesia

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ABSTRACT

Competitive fencing is an open-skill combat sport in which perception, anticipation, decision-making, and action occur under severe temporal pressure. This review synthesised evidence on cognitive performance determinants in fencing, with emphasis on sport-specific anticipation and visual attention, reaction and response selection, and trainability. A structured Scopus search was conducted in accordance with PRISMA 2020 and identified 403 records; 15 duplicates were removed, 388 titles and abstracts were screened, 70 full texts were assessed, and 18 studies were included. Eligibility was defined using a PICOS framework, and study quality and relevance were appraised with a prespecified four-domain FICO rubric (Focus, Information, Context, Outcome). Because the included studies used heterogeneous designs and non-comparable outcome operationalisations, evidence was synthesised narratively and thematically following the Thomas and Harden approach rather than quantitatively pooled. The evidence indicates that expertise is expressed primarily through sport-specific anticipation, weapon-dependent visual search, and efficient response selection and inhibition, whereas generic simple reaction time is less discriminative. Training interventions improved attention or broader cognitive function, but transfer to isolated reaction-time outcomes was inconsistent. The current screening record does not contain a reproducible inter-rater agreement statistic; accordingly, no Cohen's kappa value is reported without verification. Larger longitudinal studies, standardised fencing-specific measures, and ecologically valid designs are needed.

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Corresponding Author:

Ade Zalindro,
Universitas Negeri Padang,
Email: zalindro@fik.unp.ac.id

Introduction

Fencing ranks among the oldest Olympic sports, and it is often held up as the archetypal open-skill combat discipline. Two athletes trade offensive and defensive actions across foil, épée, and sabre, all inside a fast-moving, adversarial environment. Contemporary analyses argue that winning at this level is not purely a matter of physical and physiological capacity. The speed and quality of perceptual and cognitive processing under time pressure matter just as much (De Quel & Bennett, 2019; Holmes & Bottoms, 2026). The sport also carries intermittent, high-intensity demands and a notable injury burden, both of which point to its physical rigour (Wong et al., 2025). Talent-identification work in youth athletes, meanwhile, has long tried to isolate the motor and perceptual attributes that predict later success (Zhao et al., 2019). And yet the margins that decide bouts are usually measured in milliseconds. That reality puts cognitive-motor performance at the centre of the picture, even though it remains comparatively understudied.

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The central construct in this review is cognitive performance under temporal and adversarial pressure: the capacity to detect task-relevant cues, anticipate an opponent's action, select an appropriate response, and initiate or inhibit movement at the appropriate moment. Here, perception refers to the extraction of visually relevant information; anticipation refers to using pre-response kinematic, spatial, or contextual cues to predict an opponent's action; attention refers to selective or sustained allocation of processing resources; and decision-making refers to selecting, withholding, or amending a response among competing action alternatives. In fencing, temporal pressure denotes the very short interval available for these operations before the opponent's action changes the available response options. These processes are therefore treated as components of a perception-action loop rather than as isolated traits.

A good deal of empirical work has compared fencers with non-athletes, and experts with novices, on perceptual and motor tasks. The cross-sectional evidence is fairly consistent. Fencers show faster reaction times, greater accuracy, and higher movement velocity than matched controls (Akpinar & Beyaz, 2018). Dual-response and electromyographic studies add another layer: elite fencers achieve shorter total response times through earlier neuromuscular onsets, even though their movement execution is slower (Williams & Walmsley, 2000). Neurophysiological work has pushed these behavioural findings further, documenting enhanced early visual-attentional processing and more efficient response selection in top-level fencers. It has also tied athletic expertise to the idea of "neural efficiency" in cortical activity (Del Percio et al., 2007; Del Percio et al., 2008; Del Percio et al., 2009; Di Russo et al., 2006). Taken together, this literature suggests that fencing expertise shows up in the brain just as clearly as it does in behaviour.

Methodological and technological progress has also expanded the toolkit for studying these processes. Eye-tracking, for instance, has been used to characterise how fencers move their gaze and pick up information, both in the lab and in ecological competition settings (Bagot et al., 2023; Hagemann et al., 2010). Event-related potential and functional near-infrared spectroscopy paradigms, meanwhile, have shed light on the neural stages of preparation, perception, and action control (Bianco et al., 2017; Ding et al., 2025; Taddei et al., 2012). Purpose-built instruments, including light-based electronic targets and standardised computerised batteries, have sharpened the measurement of response time (de Giorgio et al., 2021; Teteris et al., 2025). Complementary reviews of neurofeedback protocols point to growing interest in training the cognitive substrates of performance directly (Tosti et al., 2024). All of these developments have produced an evidence base that is rich, but also quite heterogeneous.

The first gap is fragmentation across constructs and paradigms. Studies differ sharply in populations, weapons, tasks, and outcome measures. Some assess simple or choice reaction time, whereas others examine covert attention, postural anticipation, eye movements, or cortical potentials; these measures are rarely integrated into one fencing-specific framework. Recent broader reviews have mapped the general experimental and observational fencing literature (Holmes & Bottoms, 2026), and other systematic reviews have focused on injuries (Wong et al., 2025) or neurofeedback across sports (Tosti et al., 2024). However, these reviews do not specifically synthesise the joint evidence on reaction time, anticipation, visual attention, response selection, and decision-making in competitive fencing.

The second gap is methodological and translational. Many studies use small, homogeneous samples and laboratory tasks whose relationship to the perceptual demands of a real bout is uncertain. This creates an ecological-validity problem, while laterality and crossed-dominance may confound reaction-time comparisons and intervention studies often rely on small pilot samples. The present review therefore addresses not only whether experts are faster, but how perceptual information is selected, how action alternatives are controlled, and whether training transfers to ecologically meaningful cognitive-motor outcomes.

Together, these gaps justify a focused and timely synthesis. The primary objective of this review is to synthesise evidence on the perceptual-cognitive and cognitive-motor determinants of fencing expertise, identify the measurement paradigms used to operationalise these constructs, and evaluate evidence for their trainability. The review is structured around a PICOS framework covering fencers of any weapon and competitive level, fencing expertise or cognitive/perceptual-motor training as the exposure or intervention, relevant comparator conditions, and outcomes including reaction time, anticipation, attention, decision-making, response selection, and inhibition. The review follows PRISMA 2020 and uses thematic narrative synthesis because the included outcomes are heterogeneous and not suitable for direct quantitative pooling.

The first objective is to characterise the perceptual, cognitive processes that separate skilled fencers from less-skilled ones. To that end, the review offers a structured account of how anticipation, visual search, and attention operate in fencing, and of whether these processes, rather than generic perceptual speed, are what actually mark expertise.

RQ1: How do perceptual, cognitive processes (visual perception, anticipation, and attention) differentiate skilled from less-skilled fencers and characterise expert fencing performance?

The second objective is to clarify the reaction-time and response-selection characteristics tied to fencing expertise, together with the paradigms used to measure them. On this front, the review synthesises behavioural and neural evidence on speed, decision-making, and inhibitory control in fencers.

RQ2: What reaction-time and response-selection (decision-making and inhibition) characteristics are associated with fencing expertise, and how are they measured?

The third objective is to evaluate which training and psychological interventions can modify cognitive, motor performance in fencers. Where the novelty lies is in the integration: perception, decision, and action are brought together into one evidence-based synthesis that spans behavioural, neural, and applied research and speaks directly to practice.

RQ3: Which training and psychological interventions have been shown to modify cognitive, motor performance (reaction time, attention, and anticipation) in fencers?

Method

Research Design and Framework

For this study, a systematic literature review felt like the right fit. It gives a transparent, replicable way to locate, appraise, and synthesise the available evidence on a clearly defined question, and it keeps the bias that tends to creep into narrative overviews in check (Tranfield et al., 2003). We also conducted and reported the review in line with the PRISMA 2020 statement (Page et al., 2021). That guidance essentially updates and operationalises the earlier reporting standards for systematic reviews in the biomedical and behavioural sciences (Liberati et al., 2009). The PRISMA framework shaped how we handled identification, screening, eligibility, and inclusion, and it dictated how decisions were documented at every step. That way, the whole selection process stays auditable and reproducible.

Protocol and Registration

The manuscript does not report a PROSPERO registration number or a publicly accessible protocol. This status should be verified against the authors' records before resubmission and stated explicitly as either a registration identifier or a declaration that the review was not registered.

Search Strategy

We built the search around a structured Boolean string in Scopus. Population terms for fencing were combined with outcome terms for the cognitive-motor constructs of interest, and truncation via the asterisk captured morphological variants. The field code TITLE-ABS-KEY restricted matching to title, abstract, and keyword fields. The exact search string was:

TITLE-ABS-KEY (("fencing" OR "fencer" OR "épée" OR "epee" OR "foil" OR "sabre") AND ("reaction time" OR "response time" OR "anticipation" OR "decision-making" OR "visual search" OR "perceptual-cognitive" OR "attention" OR "response selection" OR "inhibition"))*

Database and Information Sources

Scopus was the sole bibliographic database searched. It provides broad indexing across sport science, human movement science, psychology, neuroscience, and allied health journals and allows reproducible export of bibliographic metadata. The single-database strategy was a pragmatic scoping decision rather than a claim of complete retrieval, and no formal sensitivity analysis comparing database coverage was performed. Consequently, database selection bias remains a limitation. In response to the reviewer recommendation, the revised manuscript makes this limitation explicit rather than introducing unverified coverage statistics. A future update should supplement Scopus with SPORTDiscus, PsycINFO, Web of Science, and/or PubMed and compare the incremental yield of each database.

Eligibility Criteria

Eligibility was prespecified using the PICOS framework (Table 1) and explicit inclusion and exclusion criteria (Table 2). Studies were eligible when they investigated fencers of any weapon or competitive level and reported at least one outcome related to reaction time, anticipation, attention, decision-making, response selection, inhibition, or closely related cognitive-motor performance. Studies were excluded when the sample was not fencing-specific, the outcome was purely physiological, nutritional, injury-related, or laterality-only without a cognitive-motor outcome, or the report was not a peer-reviewed journal article.

Table 1. PICOS framework guiding study eligibility

Element	Definition
Population (P)	Competitive or recreational fencers (foil, épée, sabre) of any age or level, with comparison groups where relevant
Intervention / Exposure (I)	Fencing expertise or practice, or a cognitive, attentional, or perceptual–motor training intervention
Comparison (C)	Non-fencers or non-athletes, novice fencers, or control and pre-intervention conditions
Outcome (O)	Reaction or response time, anticipation, visual attention or search, decision-making, response selection or inhibition, and related cognitive–motor measures
Study design (S)	Empirical quantitative studies (experimental, cross-sectional, or intervention) published in peer-reviewed journals

Table 2. Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Language	English	Non-English
Document type	Peer-reviewed journal article	Book chapter, conference paper, editorial, or review
Publication period	2000–2026	Published before 2000
Population	Fencers of any weapon or level	Non-fencing populations, or mixed samples without fencing-specific data
Focus / outcome	Reaction time, anticipation, attention, or decision-making (cognitive–motor performance)	Purely physiological, nutritional, injury, or laterality-only studies without cognitive–motor outcomes
Accessibility	Full text available	Abstract only

Study Selection Process

Study selection unfolded in three sequential stages. First, duplicate records were removed. Second, titles and abstracts were screened against the predefined eligibility criteria. Third, full texts were retrieved and assessed, with exclusion reasons recorded for reports that failed one or more criteria. The final counts were 403 records identified, 15 duplicates removed, 388 records screened, 318 records excluded at title/abstract stage, 70 reports assessed in full text, and 52 reports excluded at full-text stage, leaving 18 included studies. The available manuscript and screening record do not preserve an inter-rater agreement statistic; therefore, a Cohen's kappa value is not reported here because it cannot be validly reconstructed from aggregate counts alone. Before resubmission, the authors should calculate and report agreement from the original independent screening decisions if those records are available.

Methodological Quality and Relevance Assessment (FICO)

Methodological quality and relevance were appraised with a prespecified FICO framework covering four domains: Focus, Information, Context, and Outcome. Each domain was coded as adequate (1) or inadequate (0), producing a possible score from 0 to 4. Focus assessed clarity and appropriateness of the research aim; Information assessed completeness of reporting of design, sample, and measures; Context assessed fencing specificity of participants and setting; and Outcome assessed the validity and relevance of the cognitive-motor measures. The inclusion threshold required adequacy in all four domains (4/4). All 18 studies retained for synthesis met this predefined threshold. Because FICO is a study-specific appraisal rubric rather than a universally validated risk-of-bias instrument, the review does not interpret it as equivalent to a formal design-specific risk-of-bias tool.

Data Extraction Procedure

A standardised extraction sheet captured, for each included study, the author(s) and year, the country of the corresponding research group, the study design, the sample (size, sex, and competitive level), the technology or intervention used, the cognitive-motor outcome measures, and the key findings. One caveat applies: the exported metadata did not include an affiliation field, so the country of each study was derived from the research group and reported as a descriptive attribute rather than a value extracted from the database. All extracted information was tabulated to allow systematic comparison across studies, and those tables became the foundation for both the descriptive and thematic analyses.

Quality Assessment Results

All 18 included studies satisfied the predefined FICO inclusion threshold of 4/4 domains. No lower-quality tier was retained in the final synthesis because the eligibility rule required adequacy across Focus, Information, Context, and Outcome. This all-or-none threshold should be interpreted cautiously because it does not provide the granularity of a validated design-specific risk-of-bias instrument.

Network and Bibliometric Analysis Methodology
Given the focused scope and the modest number of included studies, formal co-authorship or co-citation network mapping was not a sensible fit. Instead, we ran a descriptive bibliometric analysis on the included set. The temporal distribution of publications, the geographic distribution of research groups, and the frequency of research designs and cognitive-motor constructs were tabulated and visualised. These descriptive analyses served to characterise the maturity, geographic concentration, and methodological composition of the evidence base, not to infer citation structure.

Data Analysis and Synthesis
Evidence was combined through narrative thematic synthesis following the approach described by Thomas and Harden (2008). Findings and outcome statements were coded line by line, grouped into descriptive themes (perceptual-cognitive skill, reaction time and response control, and trainability), and then mapped onto the three research questions. Quantitative meta-analysis was not attempted because reaction time, anticipation, and attention were operationalised using non-equivalent paradigms, including electromyographic latency, computerised response time, physical-target response time, eye-tracking/occlusion measures, postural onset, and cortical potentials. Publication-bias statistics were therefore not applied; the potential for selective publication is acknowledged as a limitation of the evidence base.

Reporting and Documentation
The review complied with the PRISMA 2020 checklist for reporting systematic reviews (Page et al., 2021), which itself builds on the principles of the original PRISMA statement (Moher et al., 2009). The flow of records through identification, screening, eligibility, and inclusion is shown in the PRISMA 2020 flow diagram (Figure 1). All counts in that diagram are consistent with the abstract and results.

Results and Discussions

Study Selection Results

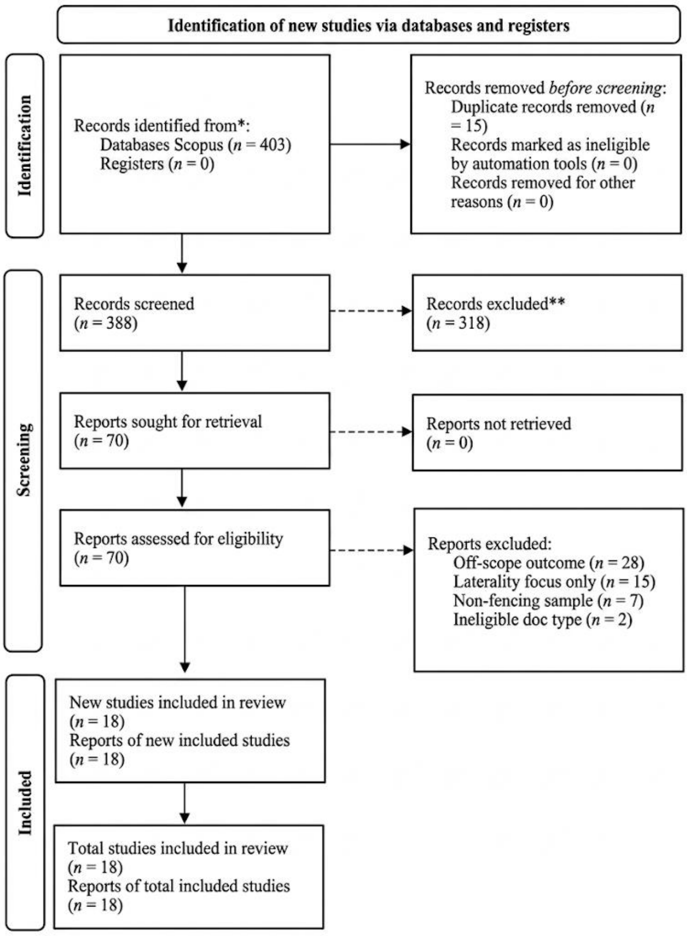

Figure 1. PRISMA 2020 flow diagram of the study selection process (adapted from Page et al., 2021).

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The Scopus search returned 403 records. After 15 duplicate records were removed, the remaining 388 went through title and abstract screening, and 318 of them were excluded as clearly irrelevant to cognitive-motor performance in fencing or as falling outside the eligibility window. Full texts were then sought for the 70 reports that remained, and each was assessed for eligibility. Every one of the 52 exclusions at this stage had a reason behind it: 28 reported outcomes unrelated to reaction time, anticipation, or decision-making (for example, nutrition, hydration, injury, or anthropometry); 15 addressed laterality or handedness without cognitive-motor performance measures; 7 involved non-fencing or mixed populations without fencing-specific data; and 2 were of an ineligible document type. Eighteen studies met every criterion and were included in the final synthesis. The complete selection process is shown in Figure 1.

Methodological Quality of Included Studies

The 18 included studies all met the prespecified FICO threshold of 4/4. Because the FICO rubric was used as an eligibility-linked appraisal rather than a continuous quality scale, the review cannot meaningfully distinguish fine-grained differences in methodological risk among the retained studies. This constraint is reflected in the interpretation of the synthesis.

Descriptive Characteristics

Between 2000 and 2025, the 18 included studies were published, and the pace clearly picked up in the later years. Ten of the eighteen (56%) appeared from 2018 onwards, with four studies in 2025 alone (Figure 2). Geographically, the work centred on Europe; Italian and French groups were the most productive, and Polish and Turkish groups followed (Figure 3). Methodologically, the corpus combined event-related potential studies, eye-tracking investigations, behavioural reaction-time experiments, biomechanical analyses, and controlled training interventions. Samples ranged from small elite cohorts to larger mixed-level groups. Table 3 summarises the characteristics and key findings of each included study, and Table 4 classifies the studies by theme, design, and cognitive-motor construct. Figure 4 rounds out the picture with the thematic composition of the evidence.

Looking at the corpus by research design adds another layer. Behavioural reaction-time and perceptual-motor experiments, along with event-related potential studies, accounted for most of the work, and they reflect a mature tradition of quantifying speed and its neural correlates in fencers. Eye-tracking studies formed a smaller but methodologically coherent cluster devoted to anticipation and visual search. Controlled interventions, by contrast, were the newest and least numerous category, appearing almost entirely in the last five years. Sample sizes tended to be small, often fewer than twenty participants, and in several elite-focused studies fewer than ten. That mirrors the practical difficulty of recruiting high-level fencers, though it constrains statistical power. Competitive level was reported inconsistently. Several studies did contrast experts with novices or non-athletes, but longitudinal follow-up was rare. So this descriptive profile, European-centred, behaviourally and neurophysiologically anchored, and only recently interventional, frames the thematic synthesis that follows. It also helps explain both the consistency of the expertise findings and the fragility of the intervention evidence.

Table 3. Summary of the included studies

Title	Author(s)	Year	Country	Key findings
Perceptual-cognitive expertise in combat sports: A narrative review and a model of perception-action	De Quel & Bennett	2019	Spain	Synthesised reaction time, anticipation, visual search and information pick-up across combat sports; expertise advantages appeared mainly in sport-specific anticipation and visual search rather than in simple reaction time.
Effects of 5-Week Brain Endurance Training on Fatigue and Performance in Elite Youth Epée Fencers	Varesco et al.	2025	France	Adding brain endurance training to fencing practice reduced sustained-attention impairment and perceived fatigue after a cognitively fatiguing task, relative to a fencing-only control group.
Fighting Left Handers Promotes Different Visual Perceptual Strategies than Right Handers: The Study of Eye Movements of Foil Fencers in Attack and Defence	Witkowski et al.	2020c	Poland	Right-handed fencers deployed different visual perceptual strategies and eye-movement patterns when facing left-handed versus right-handed opponents.
Striking a balance: Exploring attention,	Varesco et al.	2024	France	Visuospatial attention allocation did not clearly separate trained from novice

Title	Author(s)	Year	Country	Key findings
attack accuracy and speed in fencing performance				fencers, and its relationship with attack speed and accuracy was inconsistent.
Perceptual and motor performances between fencers and non-fencers	Akpinar & Beyaz	2018	Turkey	Fencers showed significantly faster reaction time, greater accuracy and faster movement velocity than matched non-fencers.
Validity and reliability of a light-based electronic target for testing response time in fencers	de Giorgio et al.	2021	Italy	The light-based electronic target was a valid and reliable device for measuring response time; elite fencers responded faster than novices across simple attack, lunge and thrust attacks.
Visual perception in fencing: Do the eye movements of fencers represent their information pickup?	Hagemann et al.	2010	Germany	Expert fencers fixated the opponent's upper trunk and weapon; eye movements partly reflected information pick-up, but occlusion revealed additional peripheral information use.
Neural correlates of fast stimulus discrimination and response selection in top-level fencers	Di Russo et al.	2006	Italy	Top-level fencers had faster reaction times together with enhanced early visual-attentional processing and more efficient response selection and inhibition at the neural level.
Response amendment in fencing: Differences between elite and novice subjects	Williams & Walmsley	2000	New Zealand	Elite fencers achieved shorter total response times through faster reaction times despite slower movement times, with earlier muscle onsets and more coherent muscle synergies.
Proactive and Reactive Motor Inhibition in Top Athletes Versus Nonathletes	Brevers et al.	2018	Belgium	Elite athletes displayed superior proactive motor inhibition, and partly reactive inhibition, compared with non-athletes.
Comparison of reaction time between beginners and experienced fencers during quasi-realistic fencing situations	Milic et al.	2020	Serbia	Reaction time increased with the number of stimulus–response alternatives, and the slope of this relationship distinguished experienced from beginner fencers, indicating superior perception–action coupling.
Effects of long-term mindfulness meditation training on attentional capacity in professional male fencer athletes	Ding et al.	2025	China	Long-term mindfulness meditation enhanced attentional capacity and altered activity in attention-related brain regions of fencers.
Application of the Vienna Test System to Measure Training-Induced Changes in Choice Reaction Time in U20 Fencers: A 12-Week Training Program Pilot Study	Teteris et al.	2025	Latvia	A 12-week reaction-training programme produced no statistically significant group-level change in choice reaction time, although moderate-to-large effect sizes were observed in a small sample.
Different proactive and reactive action control in fencers' and boxers' brain	Bianco et al.	2017	Italy	Athletes were faster than controls and fencers were more accurate than boxers, with sport-specific differences in proactive and reactive action control at the neural level.
Two Aspects of Feedforward Control During a Fencing Lunge:	Akbaş et al.	2021	Poland	Fencing expertise delayed the onset of anticipatory and early postural adjustments and modulated feedforward control

Title	Author(s)	Year	Country	Key findings
Early and Anticipatory Postural Adjustments				according to stance width and task condition.
Visual Search Strategies of Elite Fencers: An Exploratory Study in Ecological Competitive Situation	Bagot et al.	2023	France	Fencers fixated mainly on the upper torso in foil and sabre and on the lower torso in épée, revealing weapon-specific visual search strategies in ecological competition.
Neural correlates of attentional and executive processing in middle-age fencers	Taddei et al.	2012	Italy	Fencing attenuated age-related slowing of executive and attentional processing; middle-aged fencers' reaction times were comparable to young participants, with a smaller P3 delay.
Impact of life kinetik training on balance, agility, jumping, proprioception, and cognitive function in preadolescent recreational fencing athletes: a randomized controlled trial	Yarayan et al.	2025	Turkey	Life Kinetik training improved cognitive function (Stroop performance) alongside agility, balance and proprioception, relative to a control group.

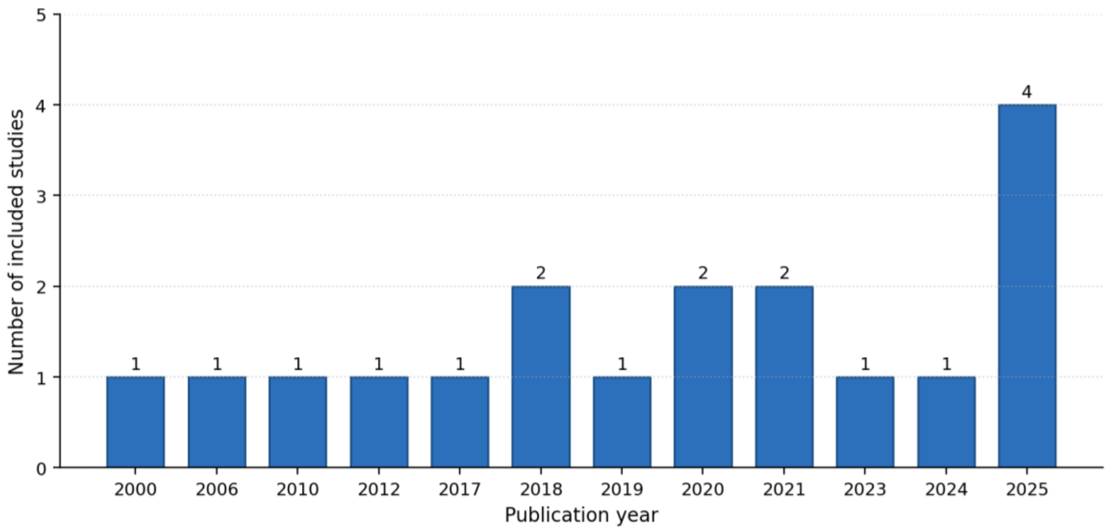

Figure 2. Temporal distribution of the 18 included studies (2000–2025).

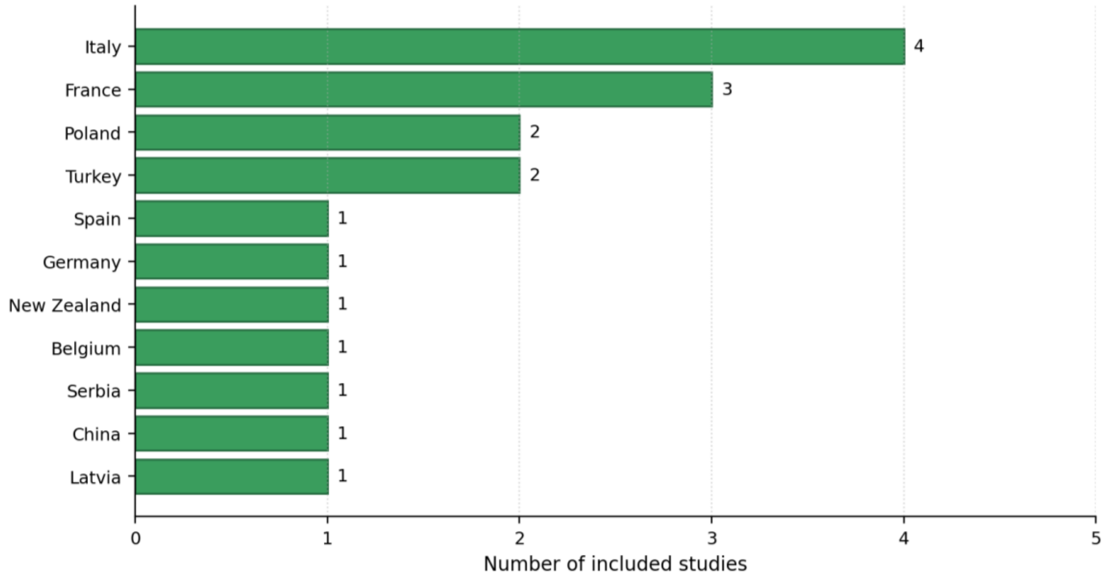

Figure 3. Geographic distribution of the included studies by first-author country.

Table 4. Classification of the included studies by theme, design, and cognitive–motor construct

Author(s) (Year)	Research design / method	Country	Theme / focus	RQ
Hagemann et al. (2010)	Experimental study (eye-movement recording with temporal/spatial occlusion; 15 expert, 15 advanced, 32 students)	Germany	Perceptual–cognitive skill & visual search	RQ1
De Quel & Bennett (2019)	Narrative review; perception–action model	Spain	Perceptual–cognitive skill & visual search	RQ1
Witkowski et al. (2020c)	Experimental eye-tracking study (12 elite female foil fencers)	Poland	Perceptual–cognitive skill & visual search	RQ1
Akbaş et al. (2021)	Biomechanical study (centre-of-pressure and EMG during the lunge; 8 elite fencers vs 9 students)	Poland	Perceptual–cognitive skill & visual search	RQ1
Bagot et al. (2023)	Eye-tracking study in a simulated competition (8 elite fencers)	France	Perceptual–cognitive skill & visual search	RQ1
Varesco et al. (2024)	Experimental laboratory study (COVAT attention test and épée test; 12 novice vs 12 trained fencers)	France	Perceptual–cognitive skill & visual search	RQ1
Williams & Walmsley (2000)	Experimental dual-response study with electromyography (3 elite, 3 novice fencers; full lunge)	New Zealand	Reaction time, response selection & neural control	RQ2
Di Russo et al. (2006)	Event-related potential study (Go/No-go and simple reaction tasks)	Italy	Reaction time, response selection & neural control	RQ2
Taddei et al. (2012)	Event-related potential study (young vs middle-aged fencers vs non-athletes)	Italy	Reaction time, response selection & neural control	RQ2
Bianco et al. (2017)	Event-related potential study (Go/No-go task; fencers, boxers and controls)	Italy	Reaction time, response selection & neural control	RQ2

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Akpinar & Beyaz (2018)	Cross-sectional comparison (19 fencers vs 19 matched non-fencers; choice reaction-time aiming task)	Turkey	Reaction time, response selection & neural control	RQ2
Brevers et al. (2018)	Experimental stop-signal study (28 elite athletes including fencers vs 25 non-athletes)	Belgium	Reaction time, response selection & neural control	RQ2
Milic et al. (2020)	Experimental video-based choice reaction study (10 beginner vs 10 experienced fencers)	Serbia	Reaction time, response selection & neural control	RQ2
de Giorgio et al. (2021)	Validity and reliability study (light-based electronic target; 95 fencers)	Italy	Reaction time, response selection & neural control	RQ2
Varesco et al. (2025)	Quasi-randomised controlled trial (5-week brain endurance training; 19 elite youth épée fencers)	France	Training & psychological interventions	RQ3
Ding et al. (2025)	Intervention study with fNIRS (20-week mindfulness meditation; 47 professional male fencers)	China	Training & psychological interventions	RQ3
Teteris et al. (2025)	Pilot intervention study (12-week reaction training; Vienna Test System; 5 U20 male fencers)	Latvia	Training & psychological interventions	RQ3
Yarayan et al. (2025)	Randomised controlled trial (8-week Life Kinetik training; 22 preadolescent recreational fencers)	Turkey	Training & psychological interventions	RQ3

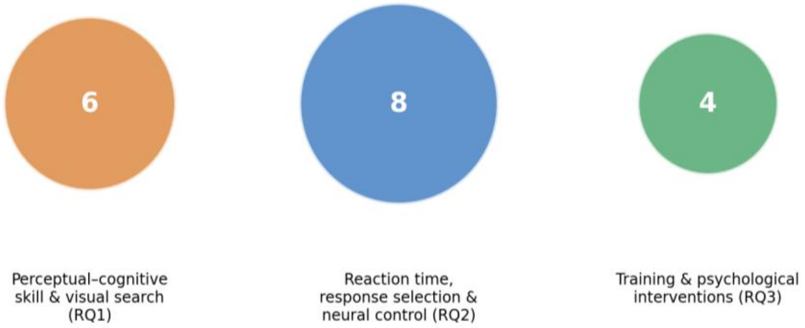

Figure 4. Thematic clustering of the included studies by research question (bubble size = number of studies).

Thematic Synthesis

Findings for RQ1: Perception, anticipation, and attention

Six studies looked at the perceptual and cognitive processes that set skilled fencers apart. A narrative synthesis spanning combat sports reached the conclusion that expertise shows up less through generic perceptual speed and more through sport-specific anticipation, visual search, and information pick-up (De Quel & Bennett, 2019). Eye-tracking work supports that pattern. Expert fencers tend to fixate on the opponent's upper trunk and weapon, yet their gaze only partially reflects the information they genuinely use, because spatial and temporal occlusion revealed a further reliance on peripheral vision (Hagemann et al., 2010). Gaze anchoring in ecological competition proved weapon-dependent. In foil and sabre, fencers fixed the upper torso; in épée, the lower torso (Bagot et al., 2023). So visual search strategies track the tactical demands of each weapon rather than following one generic expert template.

Anticipation and attention emerged as central constructs, though nuanced ones. Right-handed fencers displayed systematically different visual perceptual strategies depending on whether their opponent was left- or right-handed, which indicates that anticipatory perception adapts to the specific configuration of the bout (Witkowski et al., 2020c). At the level of movement preparation, expertise delayed the onset of anticipatory and early postural adjustments during the lunge and altered feedforward control by stance and task condition. Experts appear to exploit a more flexible preparatory strategy that commits later (Akbaş et al., 2021). The implication across these findings is straightforward: skilled fencers do not merely perceive faster. They perceive selectively and commit strategically, keeping the option to adapt open.

Not every finding favoured a clear expertise advantage, though. When visuospatial attention was measured with a covert-orienting task and linked to attack speed and accuracy, trained and novice fencers were not cleanly separated, and the relationship between attentional allocation and performance was inconsistent (Varesco et al., 2024). That contradiction matters. Laboratory attention measures may simply miss the ecologically embedded, cue-driven anticipation that characterises real bouts, so we should resist assuming generic attentional tests index fencing-specific perceptual expertise. Taken together, the RQ1 evidence supports an account where anticipation and visual search are the hallmarks of perceptual and cognitive expertise, provided the paradigms used to measure them are sufficiently sport-specific.

Findings for RQ2: Reaction time, response selection, and neural control

Eight studies examined reaction time and response selection, and they converge on a consistent conclusion: fencing expertise means faster, more efficiently controlled responses, not raw speed alone. Fencers beat matched non-fencers on choice reaction time, accuracy, and movement velocity (Akpinar & Beyaz, 2018). A validated light-based electronic target likewise showed that elite fencers out-responded novices across simple attacks, lunges, and thrust attacks (de Giorgio et al., 2021). Dual-response analyses were especially revealing. Elite fencers reached shorter total response times by initiating muscle activity earlier, even when their movement times were actually slower, and they displayed more coherent muscle synergies (Williams & Walmsley, 2000). The expert advantage thus lives in the speed and organisation of response initiation, not in gross execution.

Decision-making under uncertainty discriminated skill levels even further. Measuring reaction time across rising numbers of stimulus-response alternatives showed that the slope of the reaction-time cost separated experienced fencers from beginners, which points to superior perception-action coupling in experts (Milic et al., 2020). Neurophysiological studies clarified the mechanisms. Top-level fencers combined faster reaction times with enhanced early visual-attentional processing and more efficient response selection and inhibition in event-related potentials (Di Russo et al., 2006). A comparison of fencers, boxers, and controls then revealed sport-specific differences in proactive and reactive action control, with fencers outperforming boxers on accuracy (Bianco et al., 2017). Inhibitory control was not confined to fencing-specific tasks either. Elite athletes, fencers among them, showed superior proactive motor inhibition on a stop-signal task relative to non-athletes (Brevers et al., 2018).

These neural advantages also appear robust across the lifespan. Middle-aged fencers retained reaction times comparable to young participants and showed a smaller age-related delay in the late P3 component, which suggests that sustained open-skill practice may buffer executive and attentional processing against ageing (Taddei et al., 2012). The RQ2 evidence as a whole portrays the skilled fencer as an athlete whose behavioural speed rests on earlier neuromuscular initiation, sharper stimulus discrimination, and more efficient response selection and inhibition. All of those capacities are measurable both behaviourally and electrophysiologically. The recurring use of go/no-go and choice paradigms across these studies also signals an emerging methodological consensus around tasks that tax speed and control together.

Findings for RQ3: Training and psychological interventions

Four studies evaluated interventions aimed at modifying cognitive-motor performance, and the overall picture is that the perceptual and attentional substrates of fencing are trainable, even if evidence for reaction-time transfer is uneven. In elite youth épée fencers, a five-week programme of brain endurance training added on top of normal fencing practice reduced impairments in sustained attention and lowered perceived fatigue after a cognitively demanding task, compared with a fencing-only control group (Varesco et al., 2025). Long-term mindfulness meditation, delivered over twenty weeks, enhanced attentional capacity in professional male fencers and changed activity in attention-related brain regions as measured with functional near-infrared spectroscopy (Ding et al., 2025). Behavioural and neural evidence thus converge: attention can be strengthened through psychological training.

Interventions aimed at broader perceptual-motor coordination produced cognitive benefits too. An eight-week randomised controlled trial of Life Kinetik training in preadolescent recreational fencers improved cognitive function, indexed by Stroop performance, while also yielding gains in agility, balance, and proprioception (Yarayan et al., 2025). Integrated cognitive-motor training, in other words, can drive concurrent improvements across executive and physical domains in developing athletes. The picture for isolated reaction training is less encouraging. A twelve-week reaction-training pilot built around the Vienna Test System produced no statistically significant group-level change in choice reaction time, although moderate-to-large effect sizes appeared in a very small sample (Teteris et al., 2025). The RQ3 evidence therefore suggests that attention and cognitive control respond to targeted training, while direct reaction-time gains remain uncertain and may be masked by small samples, short durations, and ceiling effects. Practitioners seeking rapid, transferable improvements in response speed should keep that caveat in mind.

Comparative and Critical Analysis

Comparing the included studies reveals an evidence base that is methodologically diverse yet unevenly developed. Neurophysiological approaches, event-related potentials in particular, were prominent and offered the most mechanistic insight into response selection and inhibition. Eye-tracking, by contrast, dominated the study of anticipation and visual search. Behavioural reaction-time paradigms were both the most common and the most heterogeneous, running from generic aiming tasks to fencing-specific video and light-target protocols, which makes direct comparison of effect sizes difficult. Intervention research was the least mature category. Its designs were frequently pilot or quasi-experimental, samples were small, and follow-up was short, all of which limits confidence in causal claims. Cross-sectional expert-novice contrasts also outweighed longitudinal designs across the board, leaving the developmental trajectories of cognitive-motor skill poorly characterised. One methodological tension recurs throughout: the trade-off between experimental control and ecological validity. Laboratory tasks permit precise measurement, yet they may not engage the anticipatory, cue-rich processing of a real bout. That limitation became explicit when laboratory attention measures failed to separate skill groups.

A second comparative observation concerns how poorly the outcome metrics line up. Reaction time was defined one way as premotor latency inferred from electromyography, another way as button-press latency on computerised tasks, and still other ways as response time to a physical target or as the slope of latency across response alternatives. Numerically similar values may therefore index entirely different underlying processes. Anticipation was operationalised through occlusion accuracy, gaze location, and postural onset, while attention was captured through covert-orienting latency, sustained-attention decrement, and cortical potentials. This heterogeneity has two consequences. Pooling effect sizes becomes impossible, which blocks meta-analytic estimation, and it becomes unclear whether discrepant results reflect genuine disagreement or merely different constructs sharing a label. The studies that combined behavioural and neural indices (Bianco et al., 2017; Di Russo et al., 2006; Taddei et al., 2012) proved the most informative precisely because convergent measurement constrained interpretation. Multimethod designs, in that light, offer the clearest route to cumulative knowledge. Without them, the field risks accumulating isolated findings that cannot be integrated, which strengthens the case for a shared, fencing-specific measurement protocol.

Read as a whole, the evidence points to organisation and control as the essence of cognitive-motor superiority in fencing, not raw speed. Skilled fencers perceive selectively, anticipate weapon-specific cues, and commit to responses later while initiating them earlier at the neuromuscular level. Perception, decision, and action fold together into an efficient perception-action loop. This reading aligns with classic evidence that intensive practice refines the timing and sequencing of complex motor programmes rather than simply accelerating their components (Yiou & Do, 2001). It also reframes reaction time in fencing as the observable output of upstream perceptual and decisional processes.

On the theoretical side, these findings extend perception-action accounts of expertise and resonate with the idea of neural efficiency, where expert performers achieve superior outcomes through more economical cortical engagement. Electroencephalographic studies of athletes have repeatedly tied expertise to efficient pre-stimulus and task-related cortical activity (Del Percio et al., 2007; Del Percio et al., 2008; Del Percio et al., 2009), and this synthesis places fencing-specific response-selection advantages inside that broader framework. The persistence of neural and behavioural advantages into middle age adds further support. Open-skill sports such as fencing may confer durable cognitive benefits, a proposition with implications that reach well beyond competitive performance.

For coaches and federations, the review carries several actionable implications. Since expertise expresses itself through anticipation and weapon-specific visual search, perceptual training should sit inside ecologically representative situations rather than being confined to generic reaction drills. That echoes existing calls for ecological and constraints-led approaches to fencing skill and footwork development (Cree et al., 2026). Attention and cognitive control, the evidence suggests, can be trained through brain endurance training, mindfulness, and integrated cognitive-motor programmes, which supports including them in periodised preparation. The mixed results for isolated reaction-time training, meanwhile, caution against expecting rapid transfer. Complementary strands such as interhemispheric transfer training and symmetrical technical work have been shown to influence movement precision and motor performance (Johne, 2023; Witkowski et al., 2018), and applied experience from elite programmes underlines how important it is to translate such evidence into structured practice (Rhodes & Honeybone, 2013).

Placing these results alongside prior reviews clarifies what the present synthesis contributes. The 2026 scoping review by Holmes and Bottoms mapped fencing and wheelchair-fencing research broadly, while the injury meta-analysis of Wong et al. (2025) and the cross-sport neurofeedback review by Tosti et al. (2024) addressed adjacent but different questions. The present synthesis is narrower in population and broader in cognitive integration because it combines perceptual, behavioural, neural, and intervention evidence specifically around fencing performance. Within the empirical literature, Akpinar and Beyaz (2018), de Giorgio et al. (2021), Williams and Walmsley (2000), and Milic et al. (2020) converge on an expertise advantage in response speed or response organisation, although they operationalise speed differently. Hagemann et al. (2010), Witkowski et al. (2020c), and Bagot et al. (2023) show that expert visual search is selective and weapon- or opponent-dependent rather than simply faster. Akbaş et al. (2021) adds a feedforward-control perspective by showing differences in anticipatory postural regulation, while Di Russo et al. (2006), Bianco et al. (2017), and Taddei et al. (2012) provide convergent neural evidence for efficient stimulus discrimination, response selection, and inhibition. Brevers et al. (2018) further supports superior proactive motor inhibition in elite athletes. The intervention studies are more mixed: Varesco et al. (2025), Ding et al. (2025), and Yarayan et al. (2025) reported gains in attention or broader cognitive function, whereas Teteris et al. (2025) did not find a statistically significant group-level improvement in choice reaction time. Taken together, the comparison supports a control-and-organisation account of expertise while also showing that no single laboratory measure captures fencing cognition comprehensively.

A few contradictions in the literature deserve emphasis. Most studies reported expertise advantages in reaction and response control, yet laboratory attention measures did not consistently separate skill groups (Varesco et al., 2024), and a controlled reaction-training programme failed to produce significant gains (Teteris et al., 2025). Differences in ecological validity, sample size, and the specificity of the measures probably explain these discrepancies, and they warn against any simple "faster-is-better" model. Interpretation gets even more complicated because reaction time is entangled with laterality and crossed-dominance effects. Ocular dominance and handedness have themselves been linked to reaction times and performance in fencers (Barañano et al., 2025), and the well-documented left-hander advantage may covary with the very outcomes under study (Chen & Hsu, 2026).

At least three research gaps follow from this synthesis. First, longitudinal and developmental designs are scarce, so the trajectory by which cognitive-motor expertise is acquired remains unknown. Second, measurement is not standardised. Reaction time, anticipation, and attention are operationalised through incompatible paradigms, and that impedes cumulative science and meta-analysis. Third, ecological validity is under-addressed, with few studies capturing perception and decision-making during genuine adversarial bouts. Related sensorimotor determinants are also left on the sidelines. Balance and postural control distinguish fencers from other precision athletes (Herpin et al., 2010), and the interplay between physical preparation and cognitive performance (Tsolakis et al., 2010) remains insufficiently integrated with the cognitive-motor literature.

Limitations

This review has several limitations. First, it searched only Scopus, so relevant studies indexed exclusively in SPORTDiscus, PsycINFO, Web of Science, PubMed, or regional databases may have been missed. Second, inclusion was restricted to English-language journal articles, which introduces language and indexing bias. Third, the 18 included studies were heterogeneous in sample size, weapon, competitive level, and measurement paradigm, limiting direct comparison and precluding meaningful meta-analysis. Fourth, expert-focused fencing studies often used small samples, which reduces statistical power and may exaggerate instability in effect estimates; elite-sample selection may also limit generalisability to younger, female, recreational, or wheelchair fencers. Fifth, the stability of neuromuscular and neurophysiological indicators over time was rarely examined because longitudinal follow-up was uncommon. Sixth, the ecological validity of many laboratory paradigms is limited relative to genuine adversarial bouts. Seventh, the screening record available in the manuscript does not preserve an inter-rater agreement statistic, so a kappa value cannot be responsibly invented after the fact. Finally, because no validated design-specific risk-of-bias tool was used, the FICO appraisal should be interpreted as a structured relevance/quality screen rather than a substitute for formal risk-of-bias assessment.

A future research agenda should therefore prioritise four things. First, adequately powered longitudinal and randomised designs should track cognitive-motor development and test whether perceptual and attentional training transfers to competitive outcomes. Second, researchers should adopt standardised, fencing-specific measurement batteries with clear operational definitions and report reliability and validity. Third, studies should use ecologically valid paradigms, including mobile eye-tracking, virtual reality, video-based occlusion, and in-competition instrumentation, to capture anticipation and decision-making during real bouts. Fourth, future systematic reviews should use multiple bibliographic databases, a registered protocol where appropriate, independent duplicate screening, and a validated design-specific risk-of-bias instrument. Addressing these priorities would convert a promising but fragmented evidence base into a cumulative science of fencing performance.

In summary, the three research questions can be answered as follows. For RQ1, perceptual and cognitive expertise in fencing expresses itself primarily through anticipation, weapon-specific visual search, and strategically flexible movement preparation, not through generic perceptual speed. For RQ2, fencing expertise is associated with faster reaction times, underwritten by earlier neuromuscular initiation, sharper stimulus discrimination, and more efficient response selection and inhibition, all measurable through behavioural and event-related potential paradigms. For RQ3, cognitive and attentional training, whether brain endurance training, mindfulness, or integrated cognitive-motor programmes, can enhance attention and cognitive function, while the transfer of isolated reaction-time training remains uncertain.

Conclusions

This systematic review synthesised 18 studies examining cognitive performance determinants in competitive fencing. Across the evidence base, expertise was expressed most consistently through sport-specific anticipation, weapon-dependent visual search, flexible movement preparation, and efficient response selection and inhibition rather than generic perceptual speed alone. Reaction-time advantages appeared to reflect earlier neuromuscular initiation and more efficient stimulus-response control, while intervention evidence suggested that attention and broader cognitive function can be trained but that transfer to isolated reaction time is inconsistent. These conclusions are constrained by the modest and heterogeneous evidence base, single-database searching, English-language restriction, small expert samples, and the lack of a preserved inter-rater agreement statistic. The principal practical implication is that fencing training should incorporate ecologically representative perceptual and cognitive-control tasks rather than relying exclusively on generic reaction drills.

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