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REVIEW ARTICLE

A Systematic Review of Visual Hardware and Software Skills in Combat Sports: Evidence and Gaps

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ABSTRACT
Background. Combat sports place demands on athletes' visual systems due to the need for rapid perception, anticipation, and decision-making under conditions of temporal pressure and physical threat. Visual hardware and software skills are, therefore, considered critical contributors to performance. **Objectives.** The objective was to systematically synthesize existing research on these skills in combat sports, identify their relevance to performance, and highlight methodological strengths, limitations, and gaps within the current evidence base. **Methods.** Studies were obtained from various databases, including PubMed, ScienceDirect, Google Scholar, and SPORTDiscus. The search focused on systematic reviews, meta-analyses, and empirical studies published between 1990 and 2025. **Results.** A total of 21 articles were included in the review after the removal of duplicates and the full-text review process. The reviewed literature demonstrates that combat sport athletes generally show superior performance in several visual domains, including reaction time, anticipation accuracy, visual attention, depth perception, and hand–eye coordination, compared with non-athletes or less skilled counterparts. Both visual hardware and software skills were consistently associated with sport-specific performance indicators. However, findings were limited by small sample sizes, male-dominated cohorts, cross-sectional designs, laboratory-based tasks with limited ecological validity, and inconsistent reporting of effect sizes and protocols. **Conclusion.** The evidence supports the central role of visual skills in successful performance in combat sports. While current findings justify the integration of visual assessment and training into combat sport preparation, stronger causal evidence is required. Future research should prioritize longitudinal and intervention-based designs, standardized and sport-specific visual assessments, and more experimental studies on diverse combat sport athletes.

INTRODUCTION

Combat sports are characterized by highly dynamic, time-constrained, and adversarial environments in which athletes must continuously perceive, interpret, and respond to rapidly changing visual information (1). Success in combat sports such as boxing, karate, taekwondo, judo, and mixed martial arts depends not only on physical conditioning and technical proficiency, but also on the efficiency of the visual system to guide perception–action coupling under pressure (2). Unlike many non-contact or self-paced sports, combat athletes are required to anticipate an opponent's intentions, judge distance and timing with precision, and execute appropriate responses within milliseconds, often while managing physical fatigue and psychological stress. These demands position vision as a central, performance-limiting factor rather than a passive sensory input (3).

Within sport science, visual abilities are commonly conceptualized as comprising visual hardware and software skills (4). In combat sports, the integration of these hardware and software components is critical, as athletes must rapidly extract relevant visual cues from an opponent's posture, movement patterns, and spatial positioning, and translate this information into precise motor actions (5, 6). Despite its importance, visual training is often underutilized in combat sport programs. Although vision is intuitively central to success in combat sports, research in this area has historically lagged behind the investigations of physical, technical, and physiological determinants of performance (7).

The lack of a coherent synthesis of evidence presents a significant challenge for both researchers and practitioners. Coaches, sport scientists, and performance specialists increasingly seek evidence-based guidance on whether and how visual skills should be assessed and trained within combat sport programs (8, 9). Without a clear understanding of which visual skills are essential, how they relate to performance, and where current knowledge gaps exist, the translation of sport vision research into applied practice remains limited (10).

Therefore, this review synthesizes the existing scientific literature to build a comprehensive, evidence-based model of the essential visual skills required for elite performance in combat sports, identifying methodological limitations and gaps. Such work is also essential for advancing theoretical understanding, informing future research, and applied interventions. Ultimately, strengthening the evidence base in this domain has important implications for athlete development, performance optimization, and injury risk management in combat sports.

MATERIALS AND METHODS

This systematic review was conducted in accordance with the PRISMA (11) guidelines, following a rigorous and transparent methodological protocol to ensure the reliability, validity, and replicability of the findings (11).

Eligibility Criteria. This systematic review synthesizes empirical evidence on the role of visual hardware and software skills in combat sports using a PICOS-informed approach (12) (Table 1). The population of interest comprises combat sport athletes across multiple disciplines and competitive levels, reflecting the diverse perceptual–motor demands inherent to striking and grappling sports. The review examines both the assessment and targeted training of visual hardware skills, representing the physiological foundations of vision, and visual software skills. These encompass higher-order perceptual–cognitive processes essential for anticipating, interpreting, and responding to opponent actions under time pressure. Comparisons are drawn across intervention and control conditions, pre–post training designs, and between athletes of differing competitive standards, enabling evaluation of both training efficacy and performance-related visual profiles. Outcomes focus on objective measures of visual function alongside sport-specific performance indicators, thereby capturing both mechanistic and applied performance effects.

Table 1. PICOS eligibility, inclusion, and exclusion criteria.

Category	Inclusion criteria	Exclusion criteria
Population	Combat sport athletes, including boxing, karate, taekwondo, judo, wrestling, and mixed martial arts, across varying competitive levels, including novice, sub-elite, and elite performers, with no restrictions on age or sex.	Non-combat sports, recreational physical activity, or non-athlete populations (e.g., clinical or general populations with no combat sport involvement).
Intervention	Assessment and training of visual hardware and software skills, delivered either as standalone visual training programs or embedded within sport-specific training.	Purely motor, strength, conditioning, or psychological interventions without a visual component.
Comparison	Control or placebo groups, non-visual or standard sport-specific training, pre-intervention baseline measures, or comparisons between different competitive levels, training modalities, or types of visual skills (hardware versus software).	Studies that did not clearly demonstrate the critical role of visual skills under investigation in the context of combat sport performance.
Outcomes	Changes in visual performance (hardware and software skill measures) and combat sport–specific performance indicators, including response time, accuracy, tactical decision-making, strike or defensive efficiency.	Lacking objective or clearly defined visual or sport-specific performance outcomes, or reporting only subjective opinions without empirical measurement.
Study Design	Randomized controlled trials, quasi-experimental studies, cross-sectional and longitudinal observational studies, and controlled intervention studies published in peer-reviewed journals.	Editorials, commentaries, theses, dissertations, case reports, and single-subject anecdotal studies.

Search Strategy. A comprehensive and systematic search strategy was employed to identify all relevant literature examining essential visual skills in combat sports. Electronic database searches were conducted in PubMed, Crossref, Google Scholar, ResearchGate, Scopus, SPORTDiscus, ScienceDirect, Wolters Kluwer, Semantic Scholar, Elsevier, the Cochrane Database of Systematic Reviews, and OpenAthens. Searches were limited to peer-reviewed articles published in English-language journals, published between 1990 and 2025, to ensure comprehensive coverage of foundational and contemporary evidence. Full electronic search strategies for each database, including all keywords, Boolean operators, and applied filters, are provided in Supplementary Table I. Manual searches of reference lists from included studies and relevant reviews were included. The study selection process is presented in Figure 1.

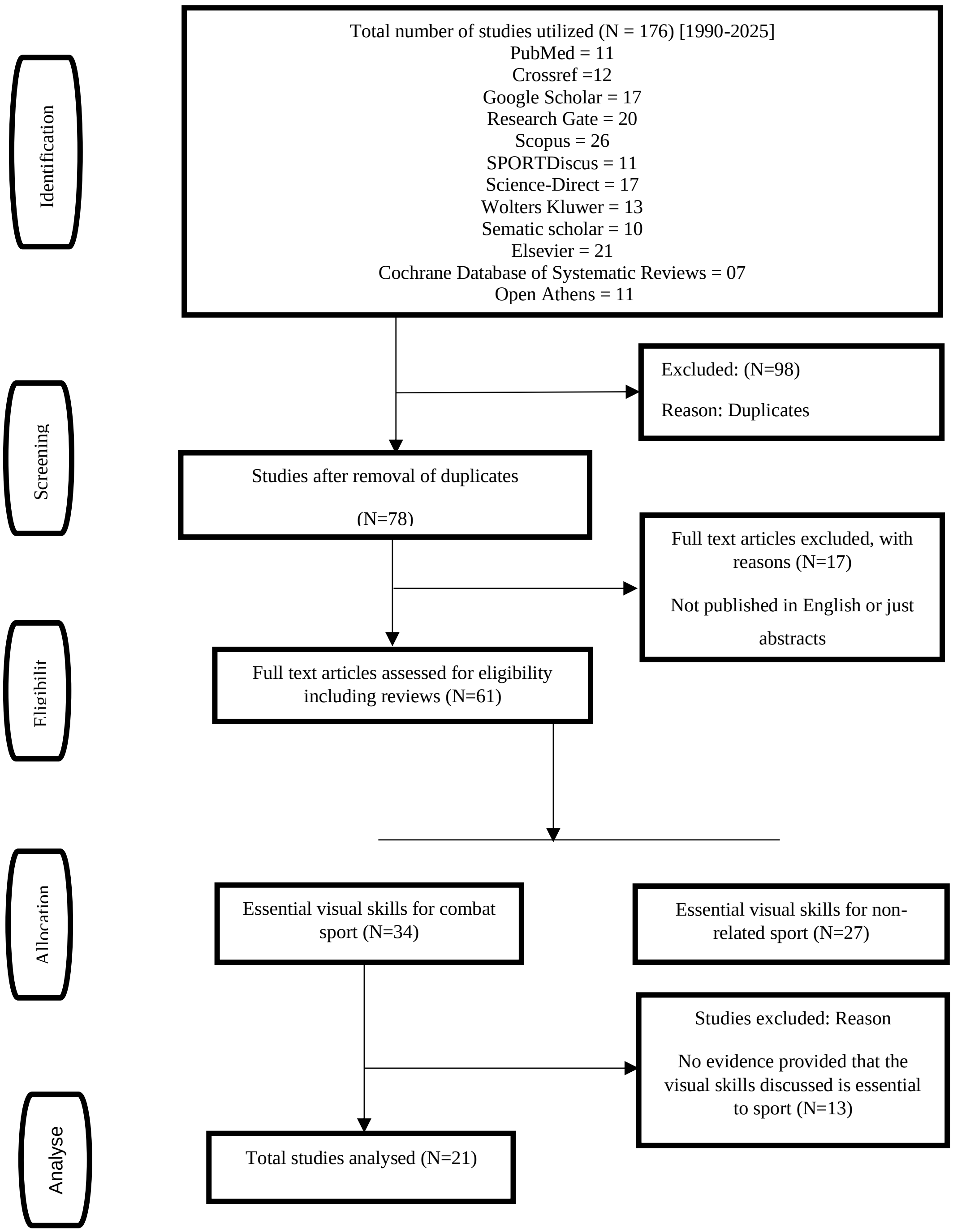

Figure 1. PRISMA flow chart of the study criteria selection process.

Data Extraction. The extracted data comprised the author(s), year of publication, country, and combat sport discipline investigated. The participants' age, methodological features were recorded, including the study design (e.g., randomized controlled trials, quasi-experimental, or cross-sectional studies). The visual skill domain captured the specific visual skills assessed or trained. Studies with unresolved missing data were excluded from the final analysis.

Risk of Bias Assessment and Methodological Quality. The risk of bias and methodological quality of all included studies will be systematically evaluated to ensure the robustness and interpretability of findings concerning essential visual skills in combat sports. Two independent reviewers (ML and MR) each assessed the study, with disagreements resolved through discussion or adjudication by a third reviewer (GJB), thereby enhancing objectivity and methodological rigor. For intervention studies, the Cochrane Risk of Bias tool (RoB 2) will be applied to evaluate bias arising from the randomization process, deviations from intended interventions, missing outcome data, measurement of outcomes, and selective reporting (13). This assessment included rating the risk of bias (low, high, or some concerns) of the following domains: random sequence generation; allocation concealment; blinding of participants and personnel; blinding of outcome assessment; incomplete outcome data; and selective reporting bias.

RESULTS

A total of 176 citations were initially identified through systematic electronic database searches. Following a comprehensive screening process, including title, abstract, and full-text evaluations, 61 full-text English-language articles were assessed for eligibility. Of these, 21 studies met the inclusion criteria and provided relevant empirical evidence on visual skills in combat sports. These studies were retained for in-depth analysis. Table 2 provides a comprehensive synthesis of essential visual hardware skills, while Table 3 presents a comprehensive synthesis of essential visual software skills.

Combat Sport Subgroup Analyses. The characteristics of studies on the various combat sport subgroup analyses are presented in Table 4. It was observed that most studies employed cross-sectional or comparative designs, frequently contrasting elite or experienced combat athletes with novices or non-athletes (5, 23, 24). Experimental interventions were less common and typically involved small sample sizes, limiting statistical power and generalizability (14, 24, 26). Several systematic reviews and meta-analyses (2, 6, 10) provide higher-level evidence, consistently confirming expertise-related advantages in perceptual–cognitive skills, although they also emphasize heterogeneity.

The studies assessed a wide range of visual hardware skills, including saccadic eye movements, accommodation facility, depth perception, vestibulo-ocular reflex function, and peripheral awareness. Visual software skills, including reaction time, anticipation, decision-making, visual memory, and visual attention, were also observed. Reaction time and hand–eye coordination were the most frequently measured outcomes, reflecting their perceived relevance to combat sports.

Table 2. Essential visual software skills that support effective perceptual–cognitive performance in combat sports.

Visual Skills	Description	References
Hand–eye coordination	The brain's ability to process visual input and convert it into precise motor actions enables athletes to respond quickly and accurately.	(14-16).
Speed of Recognition	The time it takes for an athlete to interpret a visual stimulus accurately plays a crucial role in fast-paced combat environments.	(17-19).
Saccadic Eye Movement	Saccadic eye movements are rapid, coordinated shifts of the eyes that allow combat athletes to quickly redirect their gaze toward critical visual cues in fast-changing environments.	(5, 19, 20).
Visual Reaction Time and Gaze Control	Visual reaction time and gaze control are critical skills in combat sports, as they determine how quickly an athlete can detect a stimulus and initiate an effective motor response.	(1, 5, 6, 18, 21-25).
Visual Memory and Anticipation	The ability to recall and apply visual information is vital for anticipating opponents' actions and adapting in real time.	(2, 5, 18, 23, 26, 27).
Concentration	A vital cognitive skill in combat sports, allowing athletes to maintain focus on essential visual and tactical cues while ignoring distractions in high-pressure settings.	(3, 19, 28).
Peripheral Vision and Environment Awareness	The ability of vision to allow detection of movement and cues outside direct gaze is crucial in combat sports where attacks may come from any angle.	(2, 5, 18, 26, 29).

Table 3. Fundamental visual hardware skills that provide the physiological foundation for perceptual efficiency in combat sports.

Visual Skills	Description	References
Visual Acuity	The ability to accurately fix one's vision or judgment on a moving object during play may enable players to react more swiftly and efficiently.	(5, 20, 24, 26).
Accommodation Facility	The eye's ability to quickly shift focus between near and far objects is crucial in combat sports, where athletes must track both fine details like facial expressions and broader movements such as footwork.	(5, 18, 20).
Fusion Flexibility	The ability of the eyes to maintain single binocular vision when viewing slightly different images enables accurate depth perception and three-dimensional vision.	(19, 22, 23, 26).
Fixation	The ability to maintain a steady gaze on a target is essential in combat sports for tracking an opponent's subtle movements during rapid exchanges.	(2, 18, 24).
Visual Perception	The ability to rapidly interpret visual cues such as stances, feints, and movement patterns is critical for success in combat sports.	(18, 19, 26, 30).
Depth Perception	The ability to accurately judge distances and spatial relationships between objects in three-dimensional space is a skill essential for success in combat sports.	(5, 18).

However, findings consistently indicate that simple reaction time alone is insufficient to explain performance differences (17, 23). Instead, anticipation, decision-making speed, and sport-specific visual processing emerged as stronger discriminators of expertise. Studies using combat sport-specific stimuli or tasks reported larger and more consistent effects than those relying on generic laboratory tests (2, 25).

Across most combat sports (boxing, taekwondo, karate, judo, MMA), elite or more experienced athletes showed superior visual-motor and perceptual–cognitive performance compared with less experienced combat athletes or non-athletes. These advantages were evident in faster choice reaction times, improved anticipation accuracy, enhanced visual search efficiency, and superior hand–eye coordination (2, 5, 23).

Table 4. The main characteristics of the included studies

Studies	Year	Country	Sport	Study design	Sample size	Visual measures used	Age (Years)	*p*-value
Çetin et al. (17)	2011	Turkey	Taekwondo	Cross-sectional	30	Reaction time (ms), visual attention tests	18–25	$p < 0.05$
Çetin et al. (14)	2018	Turkey	Boxing	Experimental	EXP:15 CON:14	Hand–eye coordination, Visual attention	20.4 ± 0.8	$p < 0.05$
Hammad et al. (15)	2024	Canada	Taekwondo	Cross-sectional	166	Hand–eye coordination	≤17 and >17	$p > 0.05$
Obmiński et al. (16)	2011	Poland	Boxing	Longitudinal	36	Hand–eye coordination, stimulus-response timing (s)	15–17	$p > 0.05$
Brown et al. (20)	2022	Australia	MMA	Cross-sectional	EXP: 40 CON: 40	Saccadic eye movements, visual acuity	19–44	$p < 0.05$
Mori et al. (22)	2002	Japan	Karate	Experimental	13	Reaction time (ms), Anticipation accuracy (%)	EXP: 19–22 CON: 21–43	$p < 0.05$
Vater et al. (28)	2020	Canada	General sports	Systematic review	Varied	Peripheral vision (qualitative synthesis), eye movement behavior (fixation and saccades)		NR
Yordanova et al. (23)	2023	Bulgaria	Boxing	Cross-sectional	EXP: 10 CON 10	Visual motor reaction (ms)	CON:21.2±5.4 EXP:24.4±6.9	$p < 0.05$

Abbreviations: CON, control group; EXP, experimental group; NR, not reported; MMA, mixed martial arts; pnts, points; ms, milliseconds; seconds.

Table 4. (Continued)

Studies	Year	Country	Sport	Study design	Sample size	Visual measures used	Age (Years)	*p*-value
Mahlangu et al. (31)	2024	South Africa	Boxing	Systematic review	35	Depth perception (%), accommodation facility (cycles/min), saccadic eye movements (latency/ms), reaction time (ms), hand–eye coordination (task accuracy/time), visual memory (recall accuracy), anticipation	NR	
Gou et al. (6)	2025	China	Karate	Systematic review and meta-analysis	EXP: 10 CON: 10	Visual / decision-making measures (ms), Simple reaction time(ms), Decision-making response time (ms),	10–60	$p < 0.01$
Piatysotska et al. (26)	2023	Ukraine	Karate, Taekwondo	Cross-sectional	13	Short-term visual memory (%),	19	$p > 0.05$
Wu et al. (24)	2024	China	Taekwondo, Boxing, Fencing	Experimental	30	Reaction time (ms), Response accuracy (%),	18–25	$p < 0.05$
Mahlangu et al. (5)	2024	South Africa	Boxing	Cross-sectional	90	Accommodation facility (s), saccadic eye movement (s), speed of recognition (score), peripheral awareness, hand-eye-coordination (s), visual memory	18–27	$p < 0.05$
Hernández et al. (27)	2020	Cuba	Boxing	Cross-sectional	40	Anticipation	15–16	$p < 0.05$
Zhang et al. (2)	2022	China	Boxing, Fencing, Karate, Taekwondo, Judo	Systematic review	NR	Response accuracy (%), Reaction time (ms)	NR	$p < 0.05$
Romanenko et al. (1)	2025	Ukraine	Taekwondo	Cross-sectional	57	Reaction time (ms)	18.6 ± 3.52	$p < 0.05$
Russo et al. (3)	2019	Italy	Boxing, Karate, Taekwondo, Judo, Kung-fu	Systematic review	NR	Anticipation accuracy (%), reaction time (ms), decision-making accuracy, and attention measures	NR	
De Quel et al. (18)	2016	Spain	Boxing, Fencing, Kung-fu, Karate, Taekwondo	Systematic review	NR	Reaction time (ms), anticipation accuracy (%)	NR	
Milazzo et al. (21)	2016	Australia	Combat athletes	Experimental	18	Decision-making accuracy (%), reaction decision performance, eye movement, fixation duration (ms), and number of fixations.	14–18	$p < 0.05$
Krabben et al., (19)	2018	Netherlands	Judo	Experimental	24		13–14	$p < 0.01$
Petri et al. (25)	2019	Germany	Karate	Experimental	20	Reaction time (ms), response accuracy (%), anticipation timing	17–56	$p < 0.05$

Abbreviations: CON, control group; EXP, experimental group; NR, not reported; MMA, mixed martial arts; pnts, points; ms, milliseconds.

DISCUSSION

The purpose of this review was to synthesize and critically evaluate the existing evidence on essential visual hardware and software skills in combat sports, with the aim of clarifying their relevance to performance and identifying methodological gaps within the literature. Overall, the findings demonstrate that combat sport athletes consistently show enhanced visual and perceptual–cognitive abilities compared with non-athletes or lower-skilled counterparts, supporting the central premise that vision is a key performance determinant in these sports.

Across the reviewed studies, both visual hardware skills (depth perception, accommodation facility, peripheral awareness, and oculomotor control) and software skills (reaction time, anticipation, visual attention, decision-making, and visual memory) were repeatedly associated with successful combat sport performance (27). These skills support athletes' capacity to accurately judge distance, detect relevant cues, anticipate opponents' actions, and execute timely and precise responses under competitive pressure (28, 29). Importantly, evidence suggests that no single visual ability operates in isolation; rather, effective performance emerges from the integrated functioning of multiple visual domains (30).

Vision is the most variable and influential sense affecting sports performance, consistently dominating other sensory systems and being essential for success across nearly all sports. Visual demands vary according to the different sport disciplines (21, 22). However, combat sports demand strong visual skills, which are often overlooked or under-recognized in sports vision research.

Contribution of Visual Software Skills to Combat Sport Performance

Hand–eye coordination: This skill is essential for executing complex techniques such as strikes, blocks, and evasive maneuvers in combat sports (22). It enables athletes to interpret visual stimuli and respond effectively quickly. Rapid recognition allows fighters to identify opponents' movements, punches, or kicks promptly, which is crucial for defensive actions and counterattacks (16). Enhanced speed of recognition improves reaction time, decision-making, and overall performance during high-pressure situations (25). Studies demonstrated that visual or cognitive-motor training can improve hand–eye coordination and decision-making speed, respectively, yet transfer to broader performance outcomes was inconsistent (6, 32).

Speed of recognition: This skill allows fighters to make rapid decisions based on minimal visual cues, which is essential for responding to attacks or initiating counters in real time (22). Combat athletes rely on this ability to anticipate opponents' movements, often reacting instinctively before they are consciously aware of the threat (9). Faster speed of recognition enhances both offensive and defensive decision-making, giving elite athletes a measurable competitive advantage (26). Training that focuses on visual perception and quick recognition can significantly boost an athlete's ability to process information swiftly, giving them a competitive edge in combat scenarios (25). Also, modern training tools such as virtual reality and eye-tracking systems help refine this ability by simulating realistic, high-pressure scenarios (5). Without well-developed speed of recognition, fighters are more likely to miss critical opportunities and experience delayed reactions during exchanges (33).

Saccadic eye movements and gaze patterns: These movements are essential for detecting an opponent's intentions, such as the initiation of a punch or kick, and for guiding timely motor responses (34). Effective saccadic control enhances visual tracking, working memory, and anticipation, which are vital for both offensive and defensive actions (32). In conjunction with smooth pursuit movements used to track fast-moving targets, these skills support accurate focus during dynamic exchanges, especially in sports like taekwondo (35). Effective gaze control enhances situational awareness and speed of reaction, giving athletes a competitive advantage in dynamic combat scenarios (25). Training methods such as visual tracking drills and simulated sparring improve the speed and precision of these gaze shifts (36). Elite athletes demonstrate superior saccadic efficiency, contributing to quicker decision-making and sharper reaction timing (37). Collectively, optimizing saccadic performance and gaze patterns is essential for improving visual processing and effectiveness under high-pressure competitive conditions (38).

***Visual reaction time and gaze control*:** Faster reaction times give athletes a tactical advantage in high-pressure situations. Gaze control enhances this ability by helping fighters maintain focus on key target areas while using peripheral vision to track subtle opponent movements (9). Elite fighters typically exhibit superior integration of these skills, allowing them to anticipate and counter threats with greater efficiency (36). Training methods that expose athletes to unpredictable stimuli, supported by technologies such as virtual reality and eye-tracking, further refine rapid visual processing, sharpen attentional focus, and enhance decision-making speed (10). Together, well-developed reaction time and gaze control substantially elevate responsiveness, accuracy, and overall performance in combat sports (39). Effective gaze patterns and quick reactions also enhance situational awareness and responsiveness, providing a competitive edge in dynamic combat (40).

Visual memory and anticipation: These are essential skills in combat sports, enabling athletes to recall and apply previously seen visual cues to predict and respond to their opponents' actions in real time (9),(39). Combat athletes rely on visual memory to recognize patterns, such as common attack setups or movement tendencies, allowing for more accurate and timely responses (26). Anticipation, closely tied to this memory, involves reading subtle cues like posture or weight shifts to foresee the opponent's next move (4). Elite fighters consistently outperform novices in this area due to more developed perceptual and memory-based strategies. Training methods such as video analysis, simulated sparring, and targeted memory drills enhance both skills and prepare athletes for high-pressure decision-making (41). These abilities contribute significantly to tactical awareness, reducing reaction time and improving overall performance in combat sports.

Concentration: This vital skill sustains attention throughout multiple rounds and supports consistent strategy execution, even under fatigue (7). It involves maintaining focused attention on relevant stimuli, such as an opponent's movements or tactical cues, which is crucial for effective decision-making and reaction (1). High levels of concentration enable athletes to filter out distractions, stay mentally engaged during intense moments, and execute techniques accurately (7). Elite athletes typically demonstrate superior concentration, cultivated through techniques such as mindfulness, visualization, and distraction drills, which strengthen mental resilience and performance stability (42). In high-pressure combat scenarios, where split-second lapses can result in costly errors, robust concentration is indispensable for optimal performance.

Peripheral vision and environmental awareness: These are critical skills in combat sports, enabling athletes to detect movement and cues outside their direct line of sight, an essential ability when attacks can come from any direction (3). This broader visual field supports the identification of openings, anticipation of incoming strikes, and overall situational awareness during high-speed exchanges (43). Enhanced peripheral awareness gives fighters a strategic edge by allowing them to monitor both their opponent and the surrounding space simultaneously. Training methods such as reaction balls, flashing light drills, and multi-opponent sparring improve peripheral vision and reaction accuracy (9, 43, 44). Elite athletes often demonstrate advanced peripheral processing, which supports heightened anticipation, adaptability, and defensive readiness, making this skill indispensable for maintaining control in unpredictable combat sports. Therefore, developing these skills improves overall situational awareness and responsiveness in dynamic combat situations (10).

Contribution of Visual Hardware Skills to Combat Sport Performance

Visual acuity: The sharpness or clarity of vision, which is essential in combat sports, allows athletes to detect fine details such as subtle shifts in an opponent's stance or the positioning of a fist before an attack is launched (12). High visual acuity enables fighters to recognize maneuvers, track fast movements, and anticipate strikes more accurately, particularly in high-speed sports like boxing (9). This precise visual input supports faster decision-making and more effective responses during exchanges. Athletes with superior acuity can better judge timing, distance, and target openings. Research indicates that elite combatants consistently display superior visual acuity compared to non-athletes, underscoring its critical role in both offensive and defensive performance (8, 18).

Accommodation facility: Rapid accommodation allows fighters to maintain visual clarity during fast-paced exchanges, aiding in accurate strikes and timely defensive actions (9, 36). This skill is especially vital in disciplines like karate and taekwondo, where athletes frequently alternate focus between an opponent's hands, feet, and body position (22). Combat athletes typically demonstrate faster accommodation than non-athletes due to the visual demands of their sport (13). Enhanced focusing ability facilitates quicker information processing and sharper reactions, while training tools such as accommodative flippers or lens-based drills help improve this skill under pressure. Overall, mastery of the accommodation facility provides a significant visual advantage in dynamic combat scenarios (34).

Fusion flexibility: In combat sports, this skill is essential for judging distances and spatial relationships, such as gauging how far an opponent is before initiating an attack or defense (45). Strong fusion supports precise depth perception, ensuring effective execution of offensive and defensive actions, while poor fusion can lead to misjudged distances, missed targets, or ineffective responses (24, 44). Elite fighters typically demonstrate superior fusion flexibility, allowing them to sustain spatial accuracy during fast, dynamic exchanges (46). Training approaches such as stereoscopic exercises and 3D simulations can enhance this ability, ultimately improving situational awareness and precision in technique execution (39).

Fixation: Strong fixation supports precise timing of strikes, effective defensive responses, and enhanced tactical decision-making, while poor fixation can result in missed information and increased vulnerability (37). Elite fighters consistently demonstrate superior fixation, enabling them to sustain focus under intense pressure (47). Elite fighters consistently exhibit superior fixation, maintaining focus even under intense pressure. Training methods such as strobe light drills and reaction-based exercises improve attentional control, reduce errors, and accelerate reaction speed (36). Mastery of fixation provides a clear advantage in extended exchanges, ensuring athletes remain alert, responsive, and strategically in control during high-pressure situations (48).

Visual perception: This skill encompasses key visual skills, including dynamic visual acuity, depth perception, peripheral vision, and saccadic eye movements for quick and accurate gaze shifts (22). These components work together to help combatants anticipate an opponent's actions, respond effectively, and execute techniques with precision (26). Superior visual perception enables fighters to read complex situations and adapt instantly during high-speed exchanges. Research shows that elite combat athletes process visual information more efficiently than novices, allowing for faster and more accurate decision-making under pressure (23). Developing visual perception through targeted drills and scenario-based training enhances both offensive and defensive performance in competitive combat environments.

***Depth perception*:** This is the ability to accurately judge distances and spatial relationships between objects in three-dimensional space, a skill essential for success in combat sports (2). It enables athletes to precisely time strikes, assess the range for takedowns, and evade incoming attacks with accuracy (9). Strong depth perception allows fighters to determine their opponent's exact proximity, ensuring that techniques are executed with precision and defensive actions are well-timed (5). Even minor misjudgments in distance can lead to missed strikes or poorly timed defenses, reducing performance effectiveness (30). Training approaches such as stereoscopic vision exercises and sport-specific drills enhance this skill, improving both offensive precision and defensive readiness. In high-speed combat scenarios, refined depth perception provides a decisive advantage in controlling engagement range and maintaining tactical superiority (48).

Visual and Perceptual–Cognitive Determinants of Expertise and Performance in Combat Sports. The evidence synthesized across these findings highlights vision and perceptual–cognitive efficiency as central determinants of expertise and performance in combat sports (43). (Table 4. Rather than simple reaction time alone, expert performance is consistently characterized by faster information processing, superior anticipation, efficient gaze control, and effective integration of visual cues into motor responses (33).

Across boxing and other combat disciplines, greater sport-specific experience is associated with shorter visual–motor choice reaction times, particularly for frequently practiced actions such as the jab, indicating early automatization of dominant motor patterns (9). Amateur and elite boxers consistently outperform non-athletes in visio-spatial intelligence domains, including speed of recognition, peripheral awareness, accommodation, and eye movement control, confirming that combat sport training is strongly linked to enhanced perceptual-motor functioning (34).

Importantly, the broader literature demonstrates that anticipation, decision-making speed, and visual search strategies are more predictive of success than basic reaction time measures (32). Experts rely on advanced visual cues, central gaze strategies such as visual pivot, longer quiet eye durations, and adaptive attentional control, particularly when tasks closely resemble real competitive contexts (49). These perceptual–cognitive advantages are most evident under high temporal pressure and sport-specific stimuli, underscoring the importance of ecological validity in assessment and training (5).

Visual and perceptual–cognitive training interventions further support these conclusions. While visual training does not consistently improve simple or choice reaction time or decision accuracy, it significantly enhances response speed, information-processing efficiency, and transfer to sport-specific performance, particularly when training incorporates immersive, representative designs such as VR, 3D stimuli, and action-based responses (17). This positions visual training as a valuable supplementary tool rather than a replacement for technical or physical preparation (41).

At the same time, the evidence identifies important health and monitoring considerations. A high prevalence of oculomotor and vestibulo-ocular dysfunction has been reported in combat sport athletes, likely linked to repetitive head impacts, highlighting the dual importance of vision assessment for both performance optimization and clinical screening (36).

Visual skills are trainable, sport-specific, and integral to high-level performance, but their assessment and development must prioritize ecological validity, integration with motor actions, and recognition of the combat sport discipline-specific demands (50). These insights provide a strong scientific foundation for incorporating structured visual assessment, perceptual–cognitive training, and vestibulo-ocular monitoring into long-term combat sport athlete development programs (49).

Limitations of existing studies and this review. The current body of literature examining visual skills in combat sports is characterized by several recurring methodological and conceptual limitations that constrain the strength of inferences that can be drawn. Across individual empirical studies, small sample sizes are pervasive (10). substantially reducing statistical power. These small samples are often compounded by restricted participant characteristics, including male-only cohorts (36), youth-only samples (27), or elite-only populations within narrow age ranges (18). Consequently, the generalizability of findings to female athletes, left-handed competitors, semi-professional participants, or professional combatants remains limited.

A further critical limitation is the predominance of cross-sectional research designs, which prevents causal inference regarding whether superior visual skills are a consequence of combat sport training or a pre-existing characteristic that facilitates success (10). Only a small proportion of studies attempt longitudinal monitoring or intervention-based designs, and even systematic syntheses report a scarcity of robust training studies with adequate controls (42). The lack of longitudinal data also prevents evaluation of how visual skills evolve across training cycles, competitive seasons, or developmental stages (18).

Methodological heterogeneity in visual measures represents another major constraint. This heterogeneity is further exacerbated by inconsistent reporting of protocols, task difficulty, stimulus characteristics, and testing environments, as well as by the absence of effect size reporting in several studies (10). As highlighted in broader syntheses and reviews, such variability limits comparability across studies and undermines the feasibility of quantitative meta-analysis (42).

The ecological validity of many assessments is also questionable. A substantial proportion of investigations rely on laboratory-based tasks, static images, or simplified stimuli that do not adequately capture the perceptual-motor complexity, temporal pressure, and opponent interaction inherent in real combat situations (51). While such paradigms offer experimental control, they may underestimate or misrepresent the functional visual demands of competition.

Limitations are also evident at the level of sport representation and scope. Many studies focus on a single discipline, such as only boxing, karate, taekwondo, or a narrow subset of combat sports, restricting cross-disciplinary generalization (36). Even multi-sport investigations often pool heterogeneous disciplines with differing perceptual-motor demands, potentially obscuring sport-specific adaptations (37). Furthermore, certain visual domains, such as visual acuity and visual perception, remain underrepresented or inconsistently assessed, as also noted in recent boxing-focused syntheses (9).

These limitations may be addressed through larger, more diverse samples, standardized and sport-specific visual assessments, longitudinal and intervention-based designs, and improved transparency in statistical reporting for advancing evidence-based practice in combat sport vision science.

CONCLUSION

Collectively, the reviewed research highlights the critical importance of visual hardware and software skills as foundational determinants of performance in combat sports. Across disciplines such as boxing, karate, taekwondo, and mixed martial arts, evidence consistently indicates that abilities including reaction time, anticipation, visual attention, depth perception, and hand–eye coordination underpin athletes' capacity to perceive, interpret, and respond effectively to rapidly evolving competitive environments. While visual skills appear trainable, stronger experimental evidence is required to confirm their direct transfer to competitive success. Although methodological limitations remain, the convergence of findings across diverse combat sports highlights vision as a trainable and performance-relevant component rather than a passive sensory function. Importantly, this body of work establishes a scientific rationale for integrating sport-specific visual assessment and training into athlete development programs. Through consolidating existing evidence and identifying critical gaps, the research advances understanding of how visual skills contribute to combat sport success. It provides a necessary platform for future longitudinal, ecologically valid, and intervention-based studies aimed at optimizing performance and reducing injury risk.

APPLICABLE REMARKS

- This review offers the importance of visual hardware and software skills for combat sport performance. There is a consistent body of cross-sectional, comparative, and controlled experimental studies across multiple combat sports. While findings converge on the performance relevance of reaction time, anticipation, visual attention, depth perception, and hand–eye coordination, the predominance of non-randomized and cross-sectional designs limits causal inference.
- Vision is a trainable and performance-relevant capacity. Intervention and perceptual–cognitive training studies provide evidence that selected visual and perceptual skills can be enhanced and transferred to sport-specific performance. However, variability in training protocols and limited randomized controlled trials prevent classification as high-level evidence.
- Rationale for integrating sport-specific visual assessment and training into athlete development. The recommendation is supported by converging empirical findings and applied training studies demonstrating associations between visual skill proficiency and performance. While direct cause–and–effect relationships are not uniformly established, the applied relevance is justified within current sport science practice.

AUTHORS' CONTRIBUTIONS

Study concept and design: Moeketsi Robert Mohlakoana. Acquisition of data: Moeketsi Robert Mohlakoana. Analysis and interpretation of data: Moeketsi Robert Mohlakoana. Drafting of the manuscript: Moeketsi Robert Mohlakoana. Critical revision of the manuscript for important intellectual content: Lourens Millard & Gerrit Jan Breukelman. Statistical analysis: Moeketsi Robert Mohlakoana. Administrative, technical, and material support: Moeketsi Robert Mohlakoana, Lourens Millard, and Gerrit Jan Breukelman. Study supervision: Lourens Millard and Gerrit Jan Breukelman.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest regarding the publication of this manuscript. All aspects of the research, including its design, implementation, analysis, and reporting, were conducted independently and were not influenced by any financial, professional, or personal relationships. The study was carried out without commercial or proprietary involvement that could be perceived as a potential conflict of interest.

FINANCIAL DISCLOSURE

The authors declare that they have no financial interests or conflicts of interest related to the content of this manuscript. No funding or financial support influenced the preparation, analysis, or presentation of this work.

FUNDING/SUPPORT

No funding was awarded for this study.

ETHICAL CONSIDERATION

Ethical considerations Ethical clearance to conduct this study was obtained from the University of Zululand Research Ethics Committee (No.UZREC 0691-008 PGD 2025/12).

ROLE OF THE SPONSOR

There were no sponsors for this research. The study was conducted independently, without any external funding or influence.

ARTIFICIAL INTELLIGENCE SE

Grammarly was used in this manuscript exclusively for enhancing readability and language editing. These tools did not contribute to scientific insights, data analysis, or the formulation of conclusions. Their use complies with the ethical standards outlined at aassjournal.com/content/94/). All content was reviewed, verified, and approved by the authors, ensuring full transparency and adherence to the ethical guidelines of the Annals of Applied Sport Science.

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Supplementary Table I: Full Search Strategies used Across Databases

Database	Search date	Search string (Keywords)	Limits / Filters
PubMed Crossref Google Scholar ResearchGate Scopus	Search databases were conducted between 02nd May 2025 – 15th June 2025.	‘visual skills,’ ‘hand–eye coordination,’ ‘peripheral vision,’ ‘combat sport rules,’ ‘reaction time,’ ‘speed of recognition,’ ‘accommodation facility,’ ‘visual memory,’ ‘combat sport,’ ‘depth perception,’ ‘motor learning,’ ‘cognitive function', 'vision in sport', vision, ‘Sport vision' and 'Saccadic eye movements'	Humans, in English, from 1990–2025
SPORTDiscus ScienceDirect Wolters Kluwer Semantic Scholar	Search databases were conducted between 04th 23rd June 2025 – 28th July 2025.	‘visual skills,’ ‘hand–eye coordination,’ ‘peripheral vision,’ ‘combat sport rules,’ ‘reaction time,’ ‘speed of recognition,’ ‘accommodation facility,’ ‘visual memory,’ ‘combat sport,’ ‘depth perception,’ ‘motor learning,’ ‘cognitive function', 'vision in sport', vision, ‘Sport vision' and 'Saccadic eye movements'	Humans, in English, from 1990–2025
Elsevier The Cochrane Database of Systematic Reviews OpenAthens	Search databases were conducted between 04th 13th July 2025 – 07th August 2025.	‘visual skills,’ ‘hand–eye coordination,’ ‘peripheral vision,’ ‘combat sport rules,’ ‘reaction time,’ ‘speed of recognition,’ ‘accommodation facility,’ ‘visual memory,’ ‘combat sport,’ ‘depth perception,’ ‘motor learning,’ ‘cognitive function', 'vision in sport', vision, ‘Sport vision' and 'Saccadic eye movements'	Humans, in English, from 1990–2025

Supplementary Table II: Prisma checklist

Section and Topic	Item #	Checklist item	Location where the item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Page 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 1
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 1
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 3-4
Information sources	6	Specify all databases, registers, websites, organizations, reference lists, and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 31
Search strategy	7	Present the full search strategies for all databases, registers, and websites, including any filters and limits used.	Page 31
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and, if applicable, details of automation tools used in the process.	Page 4-7
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and, if applicable, details of automation tools used in the process.	Page 4-7
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g., for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 8-14
	10b	List and define all other variables for which data were sought (e.g., participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 8-14

Section and Topic	Item #	Checklist item	Location where the item is reported
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study, and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 7
Effect measures	12	Specify for each outcome the effect measure(s) (e.g., risk ratio, mean difference) used in the synthesis or presentation of results.	Page 11-14
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g., tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 6
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics or data conversions.	Page 4-7
	13c	Describe any methods used to tabulate or visually display the results of individual studies and syntheses.	Page 8-14
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 3
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g., subgroup analysis, meta-regression).	Page 2 & 9
	13f	Describe any sensitivity analyses conducted to assess the robustness of the synthesized results.	Page 7
Reporting bias assessment	14	Describe any methods used to assess the risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 7
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 7
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 6
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 6
Study characteristics	17	Cite each included study and present its characteristics.	Page 11-14
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 7
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g., confidence/credible interval), ideally using structured tables or plots.	Page 11-14
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 11-14
	20b	Present the results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g., confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Page 9-21
	20c	Present the results of all investigations of possible causes of heterogeneity among study results.	Page 7
	20d	Present the results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Page 7
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Page7
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Page 7
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 15-21
	23b	Discuss any limitations of the evidence included in the review.	Page 21
	23c	Discuss any limitations of the review processes used.	Page 21
	23d	Discuss implications of the results for practice, policy, and future research.	Page 23

Section and Topic	Item #	Checklist item	Location where the item is reported
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 23
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 7
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Page 23
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 23
Competing interests	26	Declare any competing interests of review authors.	Page 23
Availability of data, code, and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Page 31-34