



From Physical Capacities to Shooting Performance: A Systematic Review and Conceptual Framework for Sport-Specific Assessment in 10 m Air Rifle Shooting

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Received: 20 June 2026, Approved: 20 August 2026, Published: 30 September 2026

Abstract

Study purpose. This systematic review aimed to identify and critically synthesize evidence on physical capacities and regulatory mechanisms related to postural control, technical execution, and performance in 10 m air rifle shooting, and to refine an assessment-oriented conceptual framework.

Materials and methods. PubMed/MEDLINE and Scopus were searched from database inception to 13 and 14 August 2026, respectively. After exact deduplication, 588 unique records were screened. Evidence was classified as direct air-rifle (Tier 1), closely related rifle/biathlon (Tier 2), or indirect precision-shooting evidence (Tier 3). Risk of bias was appraised qualitatively using design-specific JBI criteria, and heterogeneous findings were synthesized narratively and thematically in accordance with PRISMA 2020 and PRISMA-S reporting principles.

Results. Eighty-one reports were included in the qualitative synthesis. Direct evidence most consistently supported stability of hold, aiming accuracy, and trigger control as performance-related technical variables. Postural regulation showed mixed direct relationships with score but more consistent links with weapon/hold stability, supporting its role as a functional bridge. Direct air-rifle evidence for core endurance, upper-limb/scapular capacity, and mobility was limited and relied mainly on indirect evidence. Physiological and psychophysiological variables showed context-dependent effects and were better interpreted as modifiers. Twenty-four included reports were judged to have high methodological concern and the remainder had some concerns.

Conclusions. The evidence supports an assessment pathway in which candidate physical capacities contribute to task-specific postural regulation, which supports technical execution and, in turn, shooting outcomes. Physiological and psychophysiological factors are positioned as modifiers rather than equivalent direct determinants. The framework is evidence-informed but not yet a validated

predictive model; future studies should test its proposed assessment domains directly in 10 m air rifle athletes.

Keywords: Air Rifle Shooting, Physical Assessment, Postural Regulation, Shooting Performance, Systematic Review, Sport-Specific Testing

DOI: <https://doi.org/10.52188/ijpess.v6i3.2263>

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Introduction

Performance in 10 m air rifle shooting depends on the repeated control of a largely static body–rifle system while the athlete completes highly precise aiming and triggering actions. Small variations in body sway, rifle motion, aiming accuracy, or trigger release can alter shot placement, making the regulation of low-amplitude movement central to performance. Direct air-rifle studies consistently identify stability of hold, aiming accuracy, cleanness of triggering, and triggering timing as performance-related technical components (Ihalainen et al., 2016a; Ihalainen et al., 2017; Lang & Zhou, 2024).

Postural control is relevant to this process, but its role requires more precise interpretation than a simple assumption that less body sway always produces a higher score. In elite air-rifle shooters, postural balance contributed little directly to score in one large technical dataset, yet it was associated with stability of hold, suggesting that postural regulation may influence performance through an intermediate technical mechanism (Ihalainen et al., 2016a). Related rifle and biathlon research similarly links body sway and postural control with rifle stability, while several studies report weak, athlete-specific, or null direct associations with shot score (Mononen et al., 2007; Sattlecker et al., 2014; Spancken et al., 2021).

A second uncertainty concerns the physical capacities that may support this postural–technical system. Core or trunk endurance, upper-limb and scapular endurance, shoulder mobility, task-specific strength, and neuromuscular control are plausible contributors because athletes must sustain alignment and weapon support over repeated shot cycles. However, direct 10 m air-rifle evidence for these capacities is sparse. Much of the available evidence is derived from pistol, biathlon, or other precision-shooting contexts, where weapon mechanics, exercise load, posture, and competitive demands differ. For example, scapular endurance and selected grip-strength variables have been associated with pistol performance, whereas other core and shoulder tests have produced null findings (Sezik et al., 2023). Such evidence can inform plausibility, but it should not be presented as direct confirmation for air rifle.

Physiological regulation is also heterogeneous. Heart rate, cardiac timing, breathing behavior, fatigue, and autonomic responses can modify the conditions under which aiming and triggering occur, yet their relationships with shooting accuracy are not uniform. Direct air-rifle data show substantial shooter-specific variation in heart-rate and shooting-time relationships (Petrović et al., 2020), while biathlon studies demonstrate that substantial exercise-induced fatigue may alter technical or temporal variables without necessarily reducing shooting accuracy (Heinrich et al., 2020). This pattern argues for treating physiological variables as modifiers of postural and technical regulation rather than as equivalent primary determinants of score.

The practical problem is therefore not a shortage of candidate variables, but the absence of a transparent structure linking evidence strength, evidence proximity, physical capacities, regulatory mechanisms, technical execution, and performance outcomes. Previous reviews have mapped performance determinants in air-rifle, small-bore, pistol, and biathlon shooting (Spancken et al., 2021; Sundaram et al., 2024), but they were not designed specifically to organize evidence for sport-specific physical assessment. The novelty of the present review lies in translating heterogeneous shooting evidence into an assessment-oriented pathway while

explicitly distinguishing direct, closely related, and indirect evidence and weighting findings by methodological quality.

Therefore, this study aimed to systematically identify, critically appraise, and synthesize evidence on physical capacities and related regulatory mechanisms associated with postural control, technical execution, and performance outcomes in 10 m air rifle shooting. The review further aimed to determine how directly and consistently the available evidence supports each proposed assessment domain and to refine a conceptual framework that can guide future empirical validation.

Materials and methods

Study participants

This review did not recruit human participants. The unit of analysis was published evidence concerning competitive sport shooters or sport-shooting tasks. Evidence was eligible when it examined an athlete-related physical, biomechanical, neuromuscular, physiological, or regulatory construct in relation to shooting-position postural control, weapon/hold stability, technical execution, shooting accuracy, score, or performance stability. Because direct physical-assessment research in 10 m air rifle is limited, related precision-shooting evidence was retained only when a plausible biomechanical or regulatory transfer pathway could be identified.

Study organization

The study was conducted as a systematic review with narrative and thematic synthesis. PRISMA 2020 was used as the reporting framework for identification, selection, appraisal, and synthesis, while PRISMA-S informed transparent reporting of the literature search ([Page et al., 2021](#); [Rethlefsen et al., 2021](#)). PRISMA was therefore treated as a reporting guideline rather than as the review design itself.

Information sources and search strategy

Two primary bibliographic databases were searched: PubMed/MEDLINE through NCBI PubMed on 13 August 2026 and Scopus through Elsevier on 14 August 2026. Searches covered database inception to the search date and combined a shooting-context block (e.g., air rifle, rifle shooting, pistol shooting, biathlon, modern pentathlon, marksmanship) with a physical/regulatory block (e.g., physical fitness/capacity, strength, endurance, balance, postural control, body sway, center of pressure, core/trunk, shoulder/scapular function, flexibility/mobility, upper-limb isometric control, fatigue, respiration, heart rate, heart-rate variability, aerobic/cardiorespiratory variables, and grip strength). No year, free-full-text, or initial document-type filter was applied. The complete database-specific strategies are provided in Supplementary File 1. A preliminary literature matrix used during project development was not treated as a bibliographic database and did not contribute records to the PRISMA identification counts. Web of Science was not reported as searched because a reproducible completed search was not available.

Eligibility criteria and evidence proximity

Eligibility criteria were defined before synthesis and were applied at title/abstract and full-report stages. Full-length peer-reviewed journal articles and eligible systematic reviews/meta-analyses published in English were considered. Conference abstracts/proceedings, narrative or perspective reviews used as secondary evidence, non-English full reports, equipment-only or nutrition-only exposures, and studies without an eligible construct-to-shooting relationship were excluded from the formal synthesis. Full-text

accessibility was not treated as a scientific eligibility criterion; reports that could not be obtained after documented retrieval attempts were classified separately as reports not retrieved.

Table 1. Eligibility criteria and evidence-proximity rules

Criterion	Include	Exclude / handling rule
Population/context	Competitive sport shooters or sport-shooting tasks.	Clinical, hunting, operational military/law-enforcement, or non-sport contexts without clear transferability.
Construct	Physical capacity, postural regulation, neuromuscular control, fatigue/physiology, breathing/autonomic regulation, or shooting-specific biomechanical control.	Purely visual/cognitive, psychological-only, injury, equipment-only, or other exposures without an eligible physical/regulatory pathway.
Outcome	Shooting score/accuracy; weapon or hold stability; aiming/triggering; shooting-position postural control; related technical execution.	Outcomes unrelated to shooting, shooting posture, technical execution, or performance.
Evidence proximity	Tier 1: direct 10 m/Olympic air-rifle; Tier 2: closely related rifle/small-bore or mechanistically relevant biathlon; Tier 3: indirect precision-shooting evidence.	Remote contexts with insufficient biomechanical/regulatory transferability.
Publication type	Full-length peer-reviewed empirical journal articles; systematic reviews/meta-analyses retained separately as secondary evidence.	Conference abstracts/proceedings, editorials, perspectives, narrative reviews as formal secondary evidence, theses/books.
Language	English full report.	Non-English full report; English abstract alone was insufficient for formal inclusion.
Retrieval	All reasonable retrieval routes were attempted.	Unavailable reports were recorded as “not retrieved,” not excluded for scientific reasons.

Study selection, data extraction, and overlap control

Records were deduplicated using a predefined hierarchy: exact normalized DOI, exact PMID, and exact normalized title. Near/fuzzy title similarity was not used for automatic duplicate removal. Screening decisions were documented in a structured log, and uncertain title/abstract records were retained for full-report assessment. The review did not use independently duplicated screening; consequently, exclusion reasons and evidence classifications were re-audited against the prespecified rules before synthesis. Data extraction included author/year, study design, sample, shooting context, construct/exposure, measurement method, technical/postural outcome, shooting outcome, key statistical result, evidence proximity, framework domain, and methodological limitations.

Potentially overlapping reports were examined by comparing author groups, participant descriptions, sample sizes, testing periods, instruments, and protocols. Two Lang and Zhou reports were judged highly likely to represent the same underlying cohort/dataset and were

therefore retained as analytically distinct reports but not treated as independent participant evidence when judging evidence quantity. Other report families from Finnish air-rifle and biathlon programs and Austrian biathlon research were flagged as possible partial overlaps but were not collapsed without participant-level evidence.

Risk-of-bias appraisal and synthesis

Methodological quality was evaluated with design-specific JBI critical-appraisal logic appropriate to analytical cross-sectional, cohort, randomized, quasi-experimental, and systematic-review designs (JBI, 2026). No numerical quality score was calculated. For synthesis, appraisal findings were summarized qualitatively as “some concerns” or “high concern”; these descriptors were used to weight interpretation rather than as automatic exclusion thresholds. Particular attention was given to very small samples, uncontrolled interventions, confounding, repeated-observation dependence, overfitted statistical models, selective outcome interpretation, and overlap between reports.

Because populations, shooting disciplines, designs, exposures, instruments, and outcomes were substantially heterogeneous, no pooled meta-analysis was undertaken. Narrative/thematic synthesis followed an evidence-to-framework process: findings were first stratified by evidence proximity and evidence type, then mapped to physical capacities, postural regulation, technical execution, physiological/psychophysiological modifiers, and shooting outcomes. Consistency was judged qualitatively as relatively consistent, mixed, limited, or insufficient based on direction of findings, replication, directness, design, risk of bias, and similarity of constructs/outcomes. Causal wording was reserved for outcomes supported by an appropriate intervention design; observational findings were described as associations or relationships.

Results

Study selection

The searches identified 783 records: 276 from PubMed/MEDLINE and 507 from Scopus. Exact deduplication removed 195 records, leaving 588 unique records for title/abstract screening. Of these, 475 were excluded and 113 reports were sought for retrieval. Seven reports could not be obtained after documented retrieval attempts. Thus, 106 reports were assessed for eligibility, of which 25 were excluded after full-report/source assessment: non-English full report (n=6), ineligible secondary-study design (n=5), ineligible publication type (n=3), wrong outcome/task/construct (n=8), and wrong exposure/framework (n=3). Eighty-one reports were included in the qualitative synthesis. One pair of included reports was judged highly likely to derive from the same underlying participant dataset and was not weighted as independent evidence.

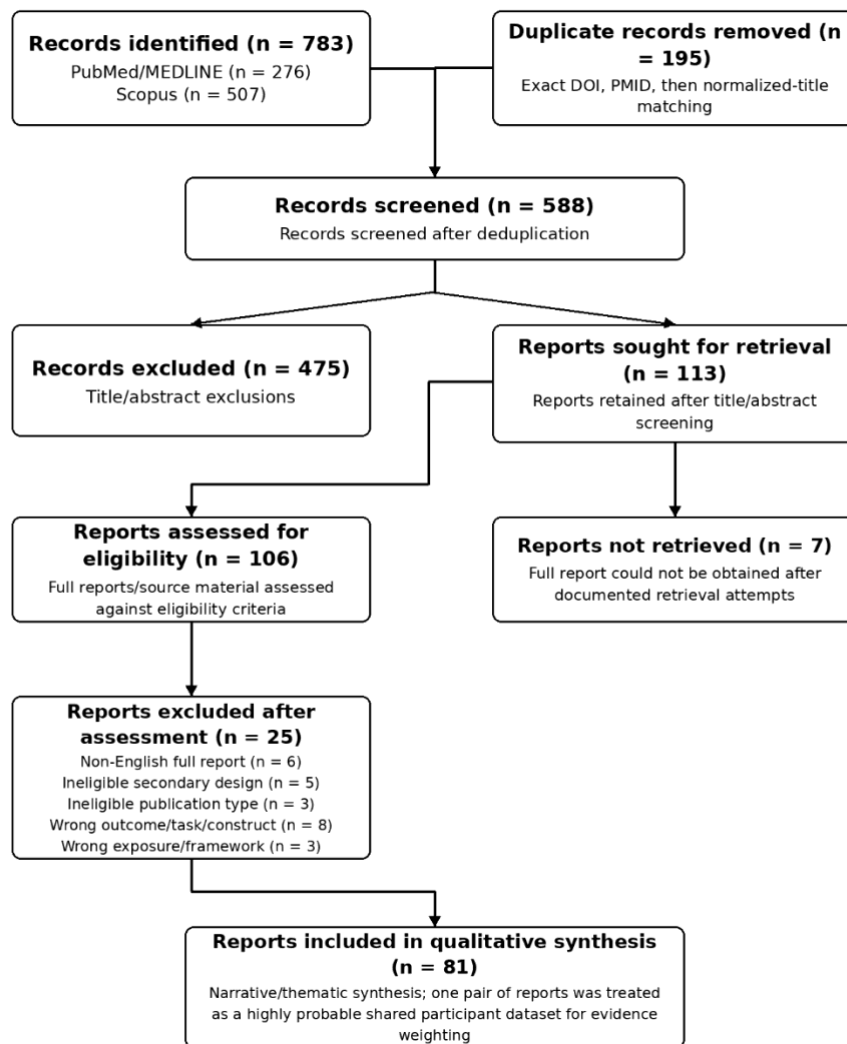


Figure 1. PRISMA 2020 flow diagram for study selection

Characteristics, evidence proximity, and methodological strength

The included evidence comprised direct air-rifle studies, closely related rifle/small-bore and biathlon studies, indirect pistol/precision-shooting studies, and a small number of shooting-specific systematic reviews/meta-analyses. Observational and repeated-measures designs predominated, while controlled interventions were comparatively uncommon and frequently small. The qualitative risk-of-bias appraisal classified 24 included reports as high concern and the remainder as having some concerns; no included report was treated as methodologically equivalent to another solely because it addressed the same construct.

Table 2 presents the studies that most directly shaped the framework and illustrates how evidence type, proximity, key finding, framework domain, and risk of bias were separated. The complete study-level matrix for all 81 included reports is provided in Supplementary Table S1.

Table 2. Key evidence informing the conceptual framework (complete matrix in Supplementary Table S1)

Study	Evidence profile (type/design, sample/context, proximity)	Construct → outcome	Key finding	Framework / RoB / overlap
Ihalainen et al. (2016a)	Primary; multivariable observational; n=40 international/national air-rifle shooters; Tier 1	Postural balance + technical components Shooting score	Four technical components explained 81% of score variance; direct postural-balance contribution <1%, but balance related to hold stability (R=.55).	Postural bridge + technical execution; some concerns
Ihalainen et al. (2016b)	Primary; longitudinal repeated measures; n=17 elite rifle shooters over 3 seasons; Tier 1	Technique-test measures Competition performance	Hold stability and triggering quality tracked competition performance across seasons.	Technical execution; some concerns
Ihalainen et al. (2017)	Primary; training-vs-competition comparison; n=13 Finnish national/junior air-rifle athletes; Tier 1	Hold, aim, trigger, postural balance Competition score	Technical model correlated with competition score (R=.76); score change related strongly to horizontal holding change.	Technical execution / postural bridge; some concerns
Lang & Zhou (2022)	Primary; cross-sectional; n=12 China national-team shooters, 60 shots each; Tier 1	Postural balance + aiming/hold/trigger Shooting score	Postural balance related to score and technical variables; within-athlete associations varied.	Postural bridge; some concerns; probable shared dataset
Lang & Zhou (2024)	Primary; multivariable observational; n=12 China national-team shooters, 60 shots each; Tier 1	Technical + postural components Shooting score	Five components explained 83.1% of variance; holding/aiming and triggering were major contributors.	Technical execution; some concerns; probable shared dataset
Petrovič et al.	Primary; ex post facto repeated	Heart rate; shooting time	Relationships were strongly	Physiological modifier; high

Study	Evidence profile (type/design, sample/context, proximity)	Construct → outcome	Key finding	Framework / RoB / overlap
(2020)	observation; n=8 experienced 10 m air-rifle shooters; Tier 1	Competition score	shooter-specific and inconsistent across athletes.	concern
Park et al. (2019)	Primary; controlled intervention; n=21 adolescent air-rifle athletes; Tier 1	Balance + respiration training Shooting record	Respiratory/muscle outcomes changed, but no between-group difference in shooting record.	Modifier/candidate capacity; high concern
Hung et al. (2021)	Primary; single- group intervention; n=8 Taiwan national air-rifle athletes; Tier 1	Functional strength + unstable-surface training Score / hold stability	Score and selected stability measures improved, but absence of control prevents strong causal attribution.	Candidate capacity / postural bridge; high concern
Spanckeen et al. (2021)	Secondary; systematic review; 14 original studies; 268 participants; Tier 1/2	Technical, postural, physiological factors Performance / skill level	Rifle stability/body sway distinguished skill in some studies; direct score relations and conditional- fitness evidence were limited.	Consistency/gap mapping; some concerns
Sundaram et al. (2024)	Secondary; systematic review/meta- analysis; 22 articles; Tier 1/3	Hold, aim, trigger, postural balance Shooting performance	Secondary synthesis supported technical determinants and moderate postural- performance associations, with heterogeneous designs.	Secondary synthesis; some concerns
Mononen et al. (2007)	Primary; correlational; n=58 novice 10 m rifle shooters; Tier	Postural balance; rifle stability Shooting accuracy	Postural and rifle-stability variables related to accuracy; two	Postural bridge; some concerns

Study	Evidence profile (type/design, sample/context, proximity)	Construct → outcome	Key finding	Framework / RoB / overlap
	2		variables explained 26% of score variance.	
Sattlecker et al. (2017)	Primary; comparative observational; n=36 biathletes across performance levels; Tier 2	Postural balance; rifle stability Standing performance	Higher-level groups showed lower body/rifle sway; correlations with standing performance were moderate.	Postural bridge; some concerns
Ihalainen et al. (2018)	Primary; repeated race simulation; n=17 Finnish biathletes; Tier 2	Hold stability, trigger, postural balance Standing performance	Technical/postural variables were related to performance and changed under load.	Modifier + technical bridge; some concerns
Köykkä et al. (2021)	Primary; task-comparison; n=22 biathletes; Tier 2	Static hold + postural control Standing performance	Static-hold measures transferred to shooting-task measures, but aiming strategy modified relationships.	Assessment transfer / postural bridge; some concerns
Sezik et al. (2023)	Primary; cross-sectional; n=28 male air-pistol shooters; Tier 3	Core/shoulder/scapular endurance Shooting performance	Scapular endurance correlated with performance; core and other shoulder-girdle tests were not significant.	Candidate upper-limb capacity; some concerns
Jin et al. (2026)	Primary; pilot RCT; n=20 national-level air-pistol shooters; Tier 3	Unstable vs stable core training Score / hold stability	Some nominal improvements favored unstable training, but multiplicity correction reduced the number of significant outcomes.	Candidate core capacity; some concerns

Study	Evidence profile (type/design, sample/context, proximity)	Construct → outcome	Key finding	Framework / RoB / overlap
Aydm et al. (2026)	Primary; RCT; n=20 trained male air-pistol athletes; Tier 3	Inspiratory muscle training Shooting accuracy	Shooting accuracy improved in the intervention group, but transferability to air rifle is indirect.	Physiological modifier; some concerns

Evidence-to-framework synthesis

Technical execution produced the most coherent evidence pattern. Direct air-rifle studies repeatedly linked stability of hold, aiming accuracy, and trigger-related variables with shooting score, and similar technical patterns were reproduced in pistol and biathlon studies. These variables were therefore positioned immediately proximal to shooting outcomes rather than being treated as physical capacities.

Postural regulation showed a different pattern. Body sway, center-of-pressure behavior, and posture differentiated expertise or related to rifle/hold stability in many studies, but direct score relationships were inconsistent within highly trained shooters. This supported a functional-bridge interpretation: postural regulation can create conditions for stable weapon control and technical execution, yet lower sway alone should not be interpreted as a universal predictor of score.

Evidence for underlying physical capacities was less direct. Core/trunk endurance was supported mainly by mechanistic reasoning, small interventions, and indirect pistol/laser-run evidence. Upper-limb/scapular/grip evidence was somewhat more convergent, but positive findings were selective and several shoulder/core tests were null. Consequently, these constructs were retained as candidate assessment capacities rather than established direct determinants. Physiological and psychophysiological variables were similarly heterogeneous; exercise load, breathing, cardiac timing, heart rate, and autonomic regulation altered technical or preparatory states in some contexts, while several studies reported no deterioration in accuracy despite substantial physiological activation.

Table 3. Evidence-to-framework synthesis and strength of support

Construct	Role, mechanism & relevant outcome	Evidence pattern (proximity & consistency)	Interpretation
Core/trunk endurance	Candidate physical capacity; Sustain trunk alignment and reduce compensatory movement Postural/hold stability	Mostly Tier 3; little direct Tier 1; Limited / inconsistent	Plausible assessment domain requiring direct air-rifle validation.
Upper-limb/scapular/grip capacity	Candidate physical capacity; Sustain weapon support and task-specific isometric control Hold/rifle stability	Mostly Tier 3; some Tier 2; Selective convergent indirect evidence	Task-specific endurance/strength is more defensible than generalized maximal strength.
Postural regulation	Functional bridge; Control body sway/COP and segmental alignment to stabilize weapon system Hold stability; aiming; score indirectly	Tier 1 + Tier 2; Mixed direct-score effect; moderate bridge support	Assess task-specific shooting-posture regulation rather than generic balance alone.
Technical execution	Proximal performance layer; Stable hold, accurate aim and clean/timed trigger release Accuracy / score	Strong Tier 1; Relatively consistent	Most evidence-supported layer immediately preceding shooting outcome.
Physiological/psychophysiological state	Modifier; Changes steadiness, breathing, cardiac/autonomic state and technical consistency Technical/postural stability; sometimes score	Mostly Tier 2/3; limited Tier 1; Mixed / context dependent	Treat as modifier, not equivalent direct determinant.

Proposed conceptual framework

The synthesis supports a four-part assessment pathway with one modifying layer. Candidate physical capacities (e.g., core/trunk endurance, upper-limb/scapular endurance, task-specific strength and mobility) are proposed to support task-specific postural regulation. Postural regulation, in turn, provides a functional bridge to technical execution, including stability of hold, aiming accuracy, trigger control, and rifle stability. Technical execution is positioned immediately before shooting outcomes because it has the strongest direct association with score. Physiological and psychophysiological states are placed as modifiers that may alter postural or technical regulation depending on context rather than as equal foundational capacities.

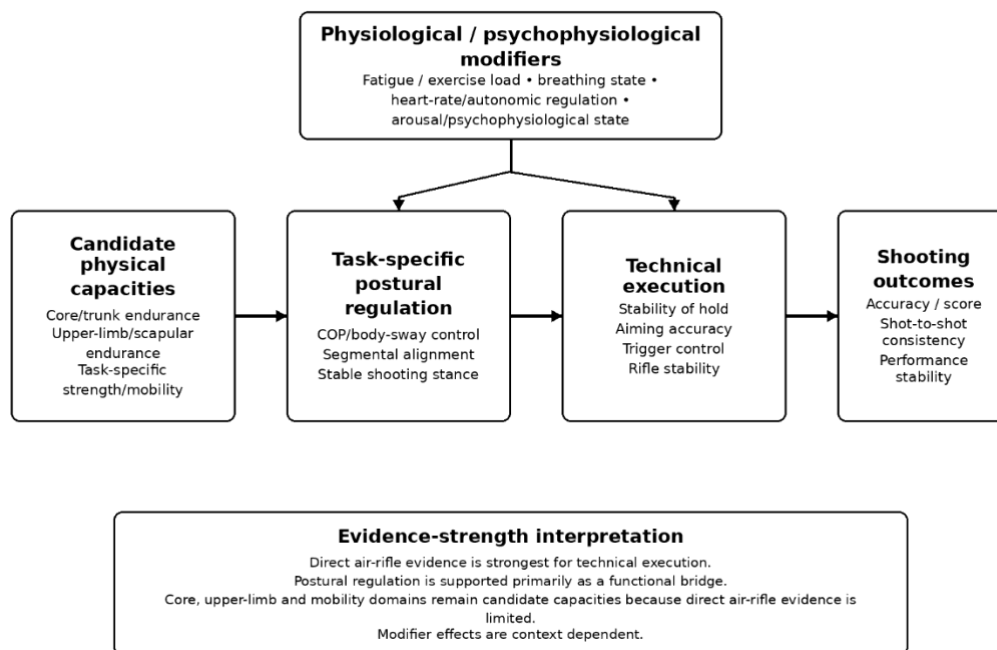


Figure 2. Evidence-informed conceptual framework for sport-specific physical assessment in 10 m air rifle shooting

Discussion

The main contribution of this review is not the identification of a new technical determinant, but the reorganization of heterogeneous shooting evidence into an assessment-oriented mechanism with explicit evidence boundaries. Across direct air-rifle studies, technical execution—especially stability of hold, aiming accuracy, and trigger control—was the most consistently performance-related level. Physical capacities were less directly evidenced. The framework therefore avoids placing strength, endurance, balance, and physiological variables beside score as if they operated at the same conceptual level. Instead, it proposes that selected capacities may support postural regulation, which helps create the mechanical conditions for reliable technical execution.

This distinction is particularly important for postural control. [Ihalainen et al. \(2016a\)](#) found that direct postural-balance contribution to score was very small, while postural balance was related to holding stability. [Mononen et al. \(2007\)](#) similarly showed direct and indirect relationships among balance, rifle stability, and accuracy in novice shooters. At the same time, several studies reported weak or null relationships between body sway and score within more highly trained groups ([Mon et al., 2019](#); [Spancken et al., 2021](#)). These findings are compatible with a ceiling or requirement interpretation: adequate postural regulation may be necessary for elite performance, but once a high level is attained, shot-to-shot differences can be dominated

by rifle stability, aiming and trigger execution rather than by whole-body sway alone. Positioning postural regulation as a functional bridge reconciles these apparently conflicting results and represents the central theoretical refinement of the framework.

The evidence also supports greater specificity in physical assessment. A generic balance test may quantify standing control without reproducing the athlete–rifle configuration, visual aiming demands, asymmetrical stance, or sustained weapon support. Conversely, task-specific static-hold and shooting-position measures have shown stronger transfer to shooting-related variables in rifle and biathlon studies (Köykkä et al., 2025). Therefore, a useful physical assessment should capture the function of the capacity under the constraints of the shooting posture rather than simply measure the maximum value of a general fitness attribute.

Core/trunk and upper-limb capacities require more cautious interpretation than in the original framework. Direct air-rifle evidence for isolated core endurance is limited. A pilot pistol RCT provides preliminary support for unstable trunk-core training, but small samples and multiplicity-adjusted results limit certainty (Jin et al., 2026). Upper-limb evidence is somewhat more specific: scapular endurance has been associated with air-pistol performance while other core/shoulder tests were not significant (Sezik et al., 2023). These findings favor assessment of task-specific endurance and positional control rather than generalized maximal strength. Contextually, recent IJPESS work in another precision sport also found higher handgrip and upper-body strength in trained archers than sedentary peers, illustrating the value of sport-specific physical profiling without implying direct transfer to air-rifle performance (Lau et al., 2025). Likewise, IJPESS research on static-balance training in karate demonstrates how a physical quality can be evaluated in relation to a specific technical task, although such cross-sport evidence was not part of the formal shooting synthesis (Cindy Lestari et al., 2024).

Physiological and psychophysiological regulation should similarly be understood as contextual modulation. Petrovič et al. (2020) observed strong heart-rate and shooting-time relationships in selected air-rifle athletes but not uniformly across the small sample. In biathlon, fatigue can alter range time, hold/rifle movement, or postural variables, yet Heinrich et al. (2020) found no significant loss of shooting accuracy across increasing physiological load. The implication is not that physiology is irrelevant, but that the effect depends on adaptation, event demands, and the technical response to the internal state. Accordingly, breathing, cardiac/autonomic variables, and fatigue are positioned outside the primary physical-capacity chain as modifiers of regulation and technical consistency.

Evidence proximity is another essential interpretive constraint. Biathlon shooting provides useful information on postural control, rifle movement, and the effects of acute physiological load, but the preceding locomotor load and shooting tempo differ markedly from static 10 m air rifle. Pistol research provides valuable evidence on grip, scapular endurance, tremor, and postural strategies, but weapon support and upper-limb mechanics differ from rifle. Therefore, Tier 2 and Tier 3 findings in the present review were used to support mechanisms or candidate assessment domains rather than to establish direct air-rifle determinants. This explicit separation addresses the transferability problem that is often obscured when all precision-shooting studies are synthesized together.

From an applied perspective, the framework suggests characteristics rather than a validated battery of tests. Assessment should be task-relevant, sensitive to sustained low-amplitude control, capable of detecting asymmetry or fatigue-related loss of regulation, and interpretable in relation to shooting-specific technical measures. Candidate domains include trunk endurance under postural-control demands, shoulder/scapular endurance or positional control, upper-limb isometric endurance, and task-specific postural stability. These domains should ideally be paired with measures of hold/rifle stability or aiming behavior so that a physical limitation is not inferred solely from a general test score. The framework does not

establish cut-offs, benchmarks, or causal predictions; those require prospective validation in air-rifle athletes.

The risk-of-bias appraisal also changes how the evidence should be read. Many shooting studies use small elite samples, repeated shots that are statistically dependent, uncontrolled interventions, or models containing multiple technical predictors relative to sample size. The evidence base is therefore stronger for repeated patterns of association than for precise causal effect estimates. Null findings were retained deliberately: the absence of shooting-score improvement after balance/respiration training in [Park et al. \(2019\)](#), for example, prevents surrogate improvements in respiratory or muscle measures from being misinterpreted as performance gains. The same principle was applied across the synthesis.

Several limitations should be considered. First, substantial heterogeneity in shooting discipline, expertise, study design, measurement method, and outcome precluded meta-analysis and required a structured narrative synthesis. Second, much of the evidence for proposed physical capacities was indirect and derived from pistol or biathlon, reducing transferability to 10 m air rifle. Third, the literature contains small samples, possible recurring national-team cohorts, and one pair of reports judged highly likely to share the same underlying dataset; this limits the apparent independence of the evidence. Fourth, seven full reports could not be retrieved despite documented attempts, and the review was restricted to English full reports. Fifth, screening was not independently duplicated, although decisions and exclusion reasons were re-audited against prespecified criteria. Finally, the framework itself has not been prospectively validated and should be regarded as an evidence-informed hypothesis for assessment design rather than a validated diagnostic or predictive model.

Future studies should test the pathway directly in 10 m air-rifle athletes by measuring candidate physical capacities, task-specific postural regulation, technical execution, and shooting outcomes within the same design. Mediation-oriented and longitudinal analyses could determine whether physical capacities influence score primarily through postural and technical mechanisms. Intervention studies should use adequate controls, prespecified outcomes, and sufficient sample sizes, and should distinguish changes in physical or biomechanical surrogates from changes in actual shooting performance.

Conclusions

This systematic review indicates that the most defensible pathway from physical capacities to 10 m air-rifle performance is indirect rather than deterministic. Stability of hold, aiming accuracy, and trigger control have the strongest direct evidence as performance-related technical variables. Task-specific postural regulation is supported as a functional bridge that can stabilize the athlete–rifle system, but its direct relationship with score is mixed. Core/trunk endurance, upper-limb/scapular endurance, task-specific strength, and mobility remain candidate physical capacities because direct air-rifle evidence is limited and much of the support is indirect. Physiological and psychophysiological factors are best interpreted as modifiers of postural and technical regulation.

Accordingly, sport-specific physical assessment should be designed to test capacities in relation to the shooting posture and technical control requirements rather than rely solely on general fitness indicators. The proposed framework provides a transparent, evidence-weighted basis for selecting and testing candidate assessment domains, but it should not be interpreted as a validated test battery or causal prediction model until prospective studies in 10 m air-rifle athletes confirm the proposed relationships.

Acknowledgment

The authors acknowledge the researchers whose work formed the evidence base for this review and the shooting-sport practitioners who provided contextual insight during

development of the assessment concept. The complete study-level evidence matrix is provided as Supplementary Table S1 to support transparency and reproducibility.

Conflict of interest

The authors declare no conflict of interest related to this article.

Data availability

The database search strategies, screening audit trail, included-study evidence matrix, exclusion log, evidence-proximity classification, and overlap notes are provided in Supplementary File 1.

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Cite this article as:

Silawati, S., & Berliana. (2026). From physical capacities to shooting performance: A conceptual framework for sport-specific assessment in 10 m air rifle shooting. *Indonesian Journal of Physical Education and Sport Science (IJPESS)*, 6(3), 460-476. <https://doi.org/10.52188/ijpess.v6i3.2263>