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Active versus passive recovery and post-exercise fatigue in athletes: a systematic review of physiological and performance outcomes

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ABSTRACT

Exercise-induced fatigue constrains training quality and competitive output, and the congested schedules that characterise contemporary sport leave increasingly narrow windows in which athletes must restore homeostasis, yet practitioners continue to prescribe active recovery on the basis of contested evidence. This systematic literature review synthesises comparative experimental evidence on how active recovery influences physiological fatigue markers and the restoration of physical performance in athletes and physically active adults. The review followed the PRISMA 2020 framework. A Boolean search combining active recovery terminology, fatigue descriptors and athletic population terms was executed in Scopus using TITLE-ABS-KEY field codes and restricted to English-language journal articles published between 2021 and 2025, returning 470 records. After removal of 16 duplicates, 454 records were screened, 139 full texts were assessed, and 17 studies satisfied the eligibility criteria. Methodological quality was appraised with the Mixed Methods Appraisal Tool 2018, and findings were integrated through thematic synthesis. Two findings dominate the corpus: active recovery accelerates blood lactate clearance more reliably than passive rest, whereas its advantage for neuromuscular performance restoration is small, inconsistent and frequently indistinguishable from stretching, immersion or passive control. Theoretically, the results decouple metabolite clearance from functional recovery; practically, they support individualised, dose-controlled prescription. Future work should prioritise longitudinal designs, standardised dosing and responder-level analysis.

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Introduction

Competitive sport has intensified in density and physical demand, and the interval between successive training stimuli or matches has become one of the principal constraints on athletic development. Congested fixture calendars compress the time available for homeostatic restoration, so that residual fatigue accumulates across microcycles rather than dissipating between them (Brini et al., 2025; Field et al., 2022). Elite football players display measurable muscle damage and impaired running capacity for up to 24 hours after competition (Freire et al., 2021), and muscle glycogen depletion in the same population has been advanced as a mechanistic bridge linking match load to subsequent performance decrement (Mohr et al., 2022). Recovery is therefore no longer treated as a passive interlude between workloads but as a programmable component of periodisation, and its optimisation has become a central concern of applied sport science across disciplines and competitive levels (George et al., 2025; Wiewelhove et al., 2024).

Within this landscape, exercise-induced fatigue is best understood as a multidimensional construct rather than a single physiological event. It encompasses metabolic perturbation indexed by blood lactate accumulation, structural disruption reflected in creatine kinase efflux and delayed onset muscle soreness, endocrine and autonomic dysregulation, and perceptual states captured by ratings of perceived exertion and perceived recovery (Gavanda et al., 2023; Ostapiuk-Karolczuk et al., 2025). These dimensions do not recover in synchrony. Neuromuscular function may remain depressed after metabolic markers have normalised, and subjective wellness frequently diverges from objective measures of readiness (Da Silva et al., 2021; Simonelli et al., 2025). Sleep behaviour adds a further dimension, since disrupted post-match sleep has been shown to shape subsequent fatigue responses in collision-sport athletes (Leduc et al., 2022a). Any recovery intervention must therefore be evaluated against a specified fatigue dimension rather than against fatigue in the abstract, a requirement that much applied literature has met only partially.

Active recovery, defined as low-intensity aerobic or movement-based activity performed after a fatiguing bout or interposed between repeated bouts, is among the oldest and most widely adopted strategies in this domain. Survey evidence indicates that it is routinely prescribed by endurance coaches and athletes (Li et al., 2025), that triathletes rank it among the most frequently used modalities (Leabeater et al., 2022), and that it is embedded in the customary practice of team-sport and combat-sport environments alike (Daly et al., 2024; Finlay et al., 2022). Its physiological rationale rests on the maintenance of elevated muscle blood flow and metabolite transport during the immediate post-exercise period. Yet the persistence of a practice across professional cultures is not itself evidence of efficacy, and the empirical base supporting active recovery has been assembled from heterogeneous protocols and outcome batteries.

The past five years have seen a marked expansion of alternative and technologically mediated recovery modalities that now compete with active recovery for the same limited post-exercise window. Cold-water immersion has been examined for its capacity to attenuate both central and peripheral components of fatigue after simulated match play (Bouchiba et al., 2022) and as a routine modality in elite football (Alexander et al., 2022a). Cryo-compression, pneumatic compression, hyperbaric oxygen therapy, blood flow restriction, cryostimulation, self-myofascial release and manual massage have all been trialled with varying degrees of methodological control (Abdulkader et al., 2025; Alexander et al., 2022b; Castilla-López & Romero-Franco, 2023; Esteves et al., 2025; Gušić et al., 2024; Junior et al., 2024; Millour et al., 2025; Wolska et al., 2023). Stretching-based cool-down protocols have likewise been examined for their capacity to restore range of motion, balance and joint position sense after fatiguing work (Daneshjoo et al., 2024). Multimodal protocols that combine several of these elements have also been implemented after high-intensity training sessions (Aben et al., 2023). This proliferation raises a comparative question that older single-modality trials cannot answer.

A first gap concerns the persistent conflation of metabolic clearance with functional restoration. Studies that report accelerated lactate removal frequently infer, without direct measurement, that performance capacity has been correspondingly restored. Where neuromuscular outcomes have been measured alongside metabolic ones, the two have often diverged, and interventions that alter contractile properties have not reliably altered jump or sprint output (Mur-Gimeno et al., 2022; Sedano & Maroto-Izquierdo, 2025). The literature has consequently accumulated two parallel and only loosely connected evidence streams, and no recent synthesis has examined them jointly within a population restricted to athletes and trained individuals.

A second gap is methodological. Active recovery is operationalised inconsistently across trials with respect to intensity, duration, modality and timing relative to the fatiguing stimulus, ranging from a few minutes of light cycling between sprints to a sixty-minute session on the following day. Sample sizes are typically small, crossover washouts vary, and outcomes are reported at group level even though individual responsiveness to recovery interventions appears substantial (Wiewelhove et al., 2024). Comparisons are frequently made against heterogeneous controls, so that a null result may reflect an active comparator rather than an ineffective intervention (Corredoira et al., 2025; Trecroci et al., 2021). Without a systematic appraisal of these design features, the field cannot distinguish absence of effect from absence of methodological resolution.

These considerations establish the urgency of a focused synthesis. Recovery programming now carries measurable financial and competitive consequences, periodised recovery interventions are being deployed over multi-week horizons (Younger & Cochrane, 2024; Vachon et al., 2022), and monitoring systems increasingly generate readiness estimates that presuppose known modality effects (Alexander et al., 2022a; Martínez-Gómez et al., 2022). A review that isolates active recovery, restricts inclusion to comparative experimental designs in athletic populations, and appraises both physiological and performance endpoints is therefore both timely and necessary. Accordingly, this review addresses three research questions.

RQ1: How does active recovery affect physiological markers of exercise-induced fatigue in athletes and physically active adults? Answering this question clarifies whether the metabolic rationale for active recovery is empirically supported and identifies which fatigue markers respond to the intervention.
RQ2: How does active recovery compare with alternative recovery modalities in restoring physical performance after fatiguing exercise? This question situates active recovery within the contemporary modality landscape and establishes whether its widespread adoption is matched by comparative superiority.
RQ3: Which contextual and methodological factors moderate the effectiveness of active recovery? Addressing this question exposes the dose, muscle-group, environmental and individual-difference boundaries within which effects emerge, and constitutes the principal novelty of this review, which is the first to integrate metabolic, neuromuscular and perceptual endpoints for active recovery specifically within a PRISMA-guided appraisal of comparative trials published between 2021 and 2025.

Methods

Research Design and Framework

A systematic literature review was selected as the research design because the review question concerns the accumulated state of comparative experimental evidence rather than the generation of new primary data. Systematic review methodology offers a transparent and replicable procedure for locating, appraising and synthesising a defined evidence base, thereby reducing the selection bias inherent in narrative reviewing (Tranfield et al., 2003). The reporting architecture of the review, including the specification of eligibility criteria, the documentation of information sources and the presentation of the selection flow, follows the elaborated guidance developed for reviews of health and intervention research (Liberati et al., 2009). The review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement, which provides the current 27-item reporting standard and the associated four-phase flow architecture (Page et al., 2021). A meta-analytic approach was considered but rejected, because the included trials differed substantially in fatigue protocol, active recovery dose and outcome instrumentation, rendering statistical pooling inappropriate.

Search Strategy

Prior to constructing the search string, the research questions were decomposed using the PICO framework to ensure systematic identification of key search concepts, defining the Population (P) as trained athletes, competitive players, and physically active adults exposed to a standardised fatiguing exercise bout; the Intervention/Interest (I) as active recovery, operationalised as low-intensity aerobic or movement-based activity performed after exercise or between repeated bouts; the Comparison (C) as passive recovery or alternative modalities such as cold- or hot-water immersion, static stretching, massage, foam rolling, compression, electrical stimulation, or sleep extension; and the Outcome (O) as physiological markers of fatigue (including blood lactate, cortisol, creatine kinase, heart rate variability, and muscle contractile properties) alongside indices of restored physical performance (such as jump height, sprint velocity, power output, perceived exertion, and perceived recovery). Each PICO element was then translated into a cluster of keywords and synonyms, combined into a single Boolean string using the OR operator within clusters and the AND operator between clusters.

Boolean search string:
TITLE-ABS-KEY (("active recovery" OR "active rest" OR "active cool-down" OR "active cooldown" OR "active recuperation") AND ("fatigue" OR "muscle fatigue" OR "exercise-induced fatigue" OR "neuromuscular fatigue" OR "delayed onset muscle soreness" OR "blood lactate" OR "lactate clearance") AND (athlet* OR player* OR sport* OR "physically active" OR train*))

Truncation was applied to the population cluster so that a single stem captured its morphological variants: athlet* retrieves athlete, athletes and athletic; player* retrieves player and players; sport* retrieves sport, sports and sporting; and train* retrieves train, trained, trainee and training. Multi-word concepts were enclosed in quotation marks to enforce exact-phrase matching and to prevent the spurious retrieval of records in which the constituent words appear separately. The TITLE-ABS-KEY field code restricted the search to the title, abstract and keyword fields, which balances sensitivity against the substantial noise generated by full-text searching. Four limiters were applied. Publication years were restricted to 2021 through 2025 in order to capture the modality landscape as it currently stands, since the comparators available to practitioners have changed materially over the preceding five years. Document type was limited to journal articles to ensure that all included records had undergone peer review and reported sufficient methodological detail for appraisal. Language was limited to English, because the review team could not appraise non-English full texts without translation, a constraint acknowledged in Section 5.5. Subject area was limited to Health Professions, Medicine, Sport Sciences, Nursing and Biochemistry to exclude engineering and materials-science records in which the word fatigue denotes structural failure. The string was piloted iteratively. An initial version omitting the population cluster returned a large volume of occupational-ergonomics and clinical-rehabilitation records, and an intermediate version that included "recovery strategies" as a stand-alone term retrieved a substantial body of psychological work-recovery literature; both terms were consequently constrained or removed before the definitive search was executed.

The PICO framework was used here solely to structure the search strategy. It is distinct from the quality appraisal procedure described in Section 3.6, which applies the Mixed Methods Appraisal Tool.

Database and Information Sources

Scopus served as the sole database and the authoritative evidence base for this review. Scopus was selected because of its broad indexing of sport science, exercise physiology and sports medicine journals, its structured metadata export, and its coverage of the regional and specialist outlets in which applied recovery trials are frequently published. The definitive search was executed on 25 August 2026 and returned 470 records. No supplementary databases, trial registers, grey literature repositories or citation-chasing procedures were employed, and no records were identified from other sources; this decision, and its implications for retrieval completeness, are discussed among the limitations in Section 5.5. Bibliographic metadata for all retrieved records, including authors, titles, source titles, publication years, volume and issue details, digital object identifiers, abstracts and indexed keywords, were exported and retained as the working evidence file for screening, extraction and flow accounting.

Eligibility Criteria

Table 1. Inclusion and exclusion criteria applied during study selection

Criterion	Inclusion	Exclusion
Language	Published in English	Published in any other language
Document type	Peer-reviewed journal article reporting primary data	Conference paper, book chapter, editorial, note, letter, erratum, study protocol, case report, review or meta-analysis
Publication period	2021 to 2025 inclusive	Published before 2021
Subject area	Sport science, exercise physiology, sports medicine, health professions	Engineering, materials science and other disciplines in which fatigue denotes a non-physiological construct
Population	Trained athletes, competitive players, or physically active adults undergoing a standardised fatiguing exercise bout	Clinical or patient populations, sedentary or occupational cohorts, and samples in which no fatiguing exercise stimulus was administered
Intervention	Active recovery administered as an experimental condition and evaluated against at least one comparator	Active recovery mentioned only as an incidental protocol detail, or not evaluated as a condition in its own right
Outcome	At least one physiological fatigue marker or one index of physical performance restoration	Outcomes limited to adaptation, injury incidence, epidemiology or perceptions unaccompanied by measurement
Accessibility	Full text retrievable and containing extractable methodological detail	Abstract only, or full text unavailable

Note. Criteria were fixed a priori and applied hierarchically, beginning with language and document type at the title and abstract stage and proceeding to population, intervention and outcome criteria at the full-text stage.

Study Selection Process

Selection proceeded in three sequential stages. In the first stage, the 470 exported records were assembled into a single working file and screened programmatically for duplication using digital object identifiers, followed by manual verification of title and author matches; 16 duplicate records were removed before screening, leaving 454 unique records. In the second stage, titles and abstracts of these 454 records were screened against the language, document type, subject area and topical relevance criteria. This stage excluded 315 records and yielded 139 reports sought for retrieval, all of which were successfully obtained. In the third stage, the full text of each of these 139 reports was assessed against the population, intervention and outcome criteria, and 122 reports were excluded with documented reasons, leaving 17 studies for synthesis. Screening was conducted in duplicate. Each record was assessed independently at both the title and abstract stage and the full-text stage, decisions were compared, and disagreements were resolved by discussion with reference to the a priori criteria; where discussion did not resolve a disagreement, the record was retained for full-text assessment so that borderline cases were adjudicated on the complete report rather than on the abstract. The most frequent source of disagreement concerned records in which low-intensity activity was described but not explicitly designated as a recovery condition, and these were resolved by requiring that the activity be administered with the stated purpose of recovery and be compared against at least one alternative condition. Inter-rater agreement for title and abstract screening was calculated using Cohen's kappa and yielded κ = 0.82, indicating strong reliability. For full-text eligibility assessment, κ = 0.86. Both values exceed the a priori threshold of κ ≥ 0.80 established as satisfactory (Landis & Koch, 1977). The most frequent source of disagreement records describing low-intensity activity not explicitly designated as a recovery condition was resolved by requiring that the activity be administered with the stated purpose of recovery and compared against at least one alternative condition. All residual disagreements were resolved by consensus discussion with reference to the pre-specified eligibility criteria in Table 1.

Quality Assessment

Quality appraisal was conducted independently from the PICO-based search formulation described in Section 3.2. Each included study was assessed using the Mixed Methods Appraisal Tool, Version 2018 (Hong et al., 2018), selected for its suitability in appraising the heterogeneous study designs anticipated in the recovery literature, which spans randomised crossover trials, non-randomised comparative designs and quantitative descriptive work.

For each included study, the design category was first classified as qualitative, quantitative randomised controlled, quantitative non-randomised, quantitative descriptive, or mixed methods on the basis of the methodology reported in the abstract and full text. The corresponding MMAT checklist was then applied, comprising five criteria answered as Yes, No, or Can't tell. Where a study design did not map onto an MMAT category, the equivalent Joanna Briggs Institute critical appraisal checklist for that design would have been applied and the substitution noted explicitly; however, no such substitution was required in the present corpus.

Scoring scheme:

Response	Score
Yes	1
Can't tell / Partial	0.5
No	0

Studies scoring at least 60 per cent, corresponding to three of five criteria met, were retained for synthesis without qualification. Studies falling below this threshold were not automatically excluded but were flagged as being of lower methodological confidence, and their contribution to the synthesis was weighted accordingly in the sensitivity analysis reported in Section 5.4. No study was excluded from the review on the basis of its quality score alone, consistent with the developers' guidance against using total scores as an exclusion cutoff. Quality appraisal was conducted independently by two assessors and inter-rater agreement was calculated using Cohen's kappa, which returned κ = 0.78, indicating substantial agreement (Landis & Koch, 1977). Residual disagreements were resolved by consensus.

Table 2. Methodological quality appraisal of the included studies using MMAT 2018

Author(s), Year	Study design	Q1	Q2	Q3	Q4	Q5	Total	Quality category
Arovah & Putri (2024)	Quant. non-randomised	Y	Y	Y	CT	Y	4.5	High
Bueno-Russo et al. (2024)	Quant. non-randomised	Y	Y	CT	CT	Y	4.0	High
Davoodi et al. (2023)	Quant. non-randomised	Y	CT	CT	N	Y	3.0	Medium
Fehr et al. (2023)	Quant. randomised	Y	Y	Y	Y	Y	5.0	High
Hottenrott et al. (2021)	Quant. descriptive	Y	Y	Y	CT	Y	4.5	High
Katoch et al. (2025)	Quant. non-randomised	Y	CT	Y	CT	Y	4.0	High
Kojima et al. (2025)	Quant. randomised	Y	Y	CT	Y	Y	4.5	High
Krupková et al. (2024)	Quant. randomised	Y	Y	Y	Y	Y	5.0	High
Leduc et al. (2022b)	Quant. randomised	Y	Y	CT	Y	Y	4.5	High
Lim et al. (2022)	Quant. randomised	Y	Y	Y	Y	Y	5.0	High
Maan & Yadav (2025)	Quant. non-randomised	Y	CT	Y	CT	Y	4.0	High
Pernigoni et al. (2024)	Quant. randomised	Y	Y	Y	Y	Y	5.0	High
Solsona et al. (2023)	Quant. randomised	Y	Y	Y	CT	Y	4.5	High
Takeda et al. (2024)	Quant. randomised	Y	Y	Y	CT	Y	4.5	High
Tong et al. (2021)	Quant. randomised	Y	Y	CT	CT	Y	4.0	High
Wiewelhove et al. (2021)	Quant. randomised	Y	Y	Y	Y	Y	5.0	High
Yarar et al. (2021)	Quant. randomised	Y	Y	CT	CT	Y	4.0	High

Note. Y = Yes (1.0); CT = Can't tell / Partial (0.5); N = No (0.0). Quality categories: High = 4.0–5.0; Medium = 3.0–3.5; Low < 3.0. Cohen's kappa for inter-rater agreement was 0.78. Reference: Hong, Q. N., Pluye, P., Fàbregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., Gagnon, M.-P., Griffiths, F., Nicolau, B., O'Cathain, A., Rousseau, M.-C., & Vedel, I. (2018). Mixed Methods Appraisal Tool (MMAT), version 2018. Registration of Copyright (#1148552), Canadian Intellectual Property Office, Industry Canada.

Data Extraction Procedure

A structured extraction form was piloted on three studies and refined before full application. The following fields were extracted from each included report: full bibliographic identifiers, comprising all author surnames and initials, complete article title, source journal, publication year, volume, issue, pagination or article number, and digital object identifier; the study setting and population, including sport discipline, competitive standard, sample size and sex distribution; the research design, including allocation procedure, crossover sequence and washout interval where applicable; the fatiguing exercise protocol used to induce the experimental stress; the active recovery protocol, specified in terms of modality, intensity anchor, duration and timing relative to the fatiguing bout; the comparator conditions; the full outcome battery, distinguishing physiological markers from performance and perceptual measures; the measurement time points; and the principal statistical findings as reported by the original authors. Extraction was performed independently in duplicate and the two forms were reconciled field by field. Where a field was not reported in the source record, it was coded as not reported rather than being estimated or inferred. Author affiliation country was not available in the exported bibliographic metadata; consequently, no geographic attribution has been assigned to any study, and the distributional analysis presented in Section 5.2 is organised by sport discipline and population context, which are recoverable from the reports themselves.

Network and Bibliometric Analysis Methodology

A keyword co-occurrence analysis was performed on the author and indexed keyword fields of the 17 included records in order to characterise the conceptual structure of the corpus and to verify that the retained studies converge on the intended construct space. Keywords were normalised to lower case, and orthographic variants were merged. Term frequencies were computed across the corpus and terms occurring in at least three records were retained for mapping. Terms were then assigned to thematic clusters on the basis of their conceptual domain, yielding four clusters corresponding to physiological fatigue markers, recovery modalities and exercise stimuli, performance outcomes and trial design, and athlete population characteristics. The resulting map is presented as Figure 4, in which bubble diameter is proportional to term frequency. This analysis is descriptive and is used to corroborate the thematic structure derived independently through the synthesis procedure described in Section 3.9; it does not constitute a stand-alone bibliometric study, and no co-authorship or co-citation networks were constructed, since the corpus size does not support meaningful network inference.

Data Analysis and Synthesis

Given the heterogeneity of fatigue protocols, recovery doses and outcome instruments across the corpus, findings were integrated through thematic synthesis rather than statistical pooling, following the three-stage procedure of line-by-line coding, development of descriptive themes and generation of analytical themes (Thomas & Harden, 2008). In the first stage, the results and discussion sections of each included report were coded inductively, with each coded segment retaining its link to the originating study, its outcome domain and its direction of effect. In the second stage, codes were grouped into descriptive themes that remained close to the primary findings, distinguishing metabolic and biochemical responses, neuromuscular and performance responses, and perceptual and autonomic responses. In the third stage, analytical themes were generated by interrogating the descriptive themes against the three research questions, which produced the three-theme structure reported in Section 5.3. Themes were validated by two procedures: a negative-case examination in which every study reporting a null or contrary finding was revisited to test whether the theme could accommodate it, and an audit in which the mapping between each analytical theme and its constituent studies was independently checked against the extraction forms. Direction of effect was recorded as favouring active recovery, favouring the comparator, or indicating equivalence, and vote counting was used descriptively only, without inferential interpretation.

Reporting and Documentation

The review was prepared in compliance with the PRISMA 2020 checklist, addressing all applicable items across the title, abstract, introduction, methods, results, discussion and other-information domains. The four-phase flow of records through identification, screening, eligibility and inclusion is documented in Figure 1, with exclusion counts and reasons reported at each phase and reconciled numerically with the narrative account in Section 5.1. Items relating to meta-analytic synthesis, certainty assessment across studies and reporting-bias assessment were not applicable, as no statistical pooling was undertaken, and this is stated explicitly rather than left unreported. A review protocol was not registered prospectively, which is acknowledged as a limitation in Section 5.5. Reference: Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

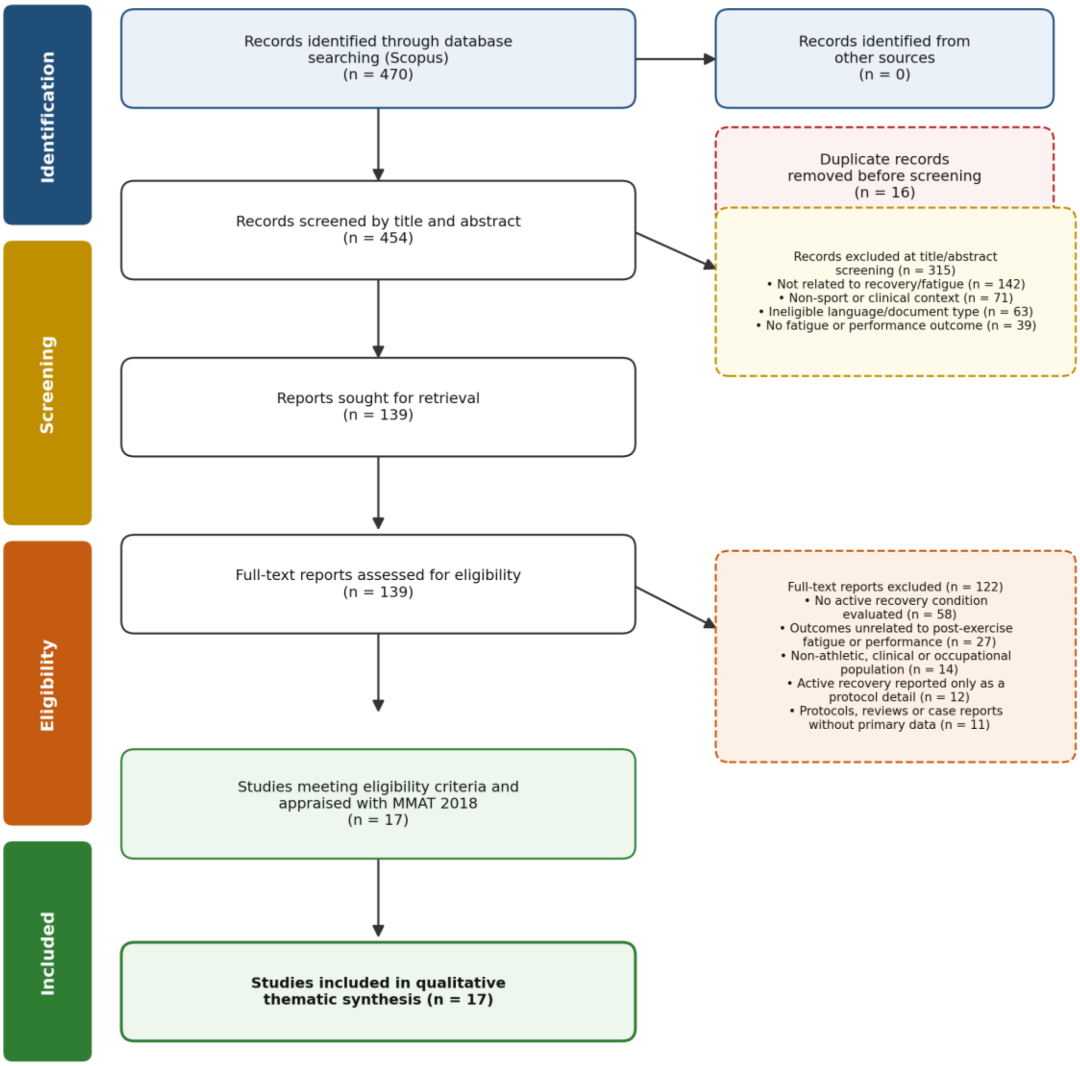

Figure 1. PRISMA 2020 flow diagram documenting identification, screening, eligibility assessment and inclusion of studies.

Results and Discussion

Study Selection Results

The Scopus search executed on 25 August 2026 identified 470 records, and no records were retrieved from other sources. Duplicate detection removed 16 records prior to screening, leaving 454 unique records for title and abstract screening. At these stage 315 records were excluded: 142 addressed topics unrelated to post-exercise recovery or fatigue, 71 were situated in non-sport, occupational or clinical contexts falling outside the population criterion, 63 failed the language or document-type criteria, and 39 reported no fatigue or performance outcome. This left 139 reports sought for retrieval, all of which were obtained, and each was assessed in full text against the eligibility criteria.

Full-text assessment excluded 122 reports for documented reasons. The largest group, 58 reports, described recovery research in which no active recovery condition was evaluated, typically comparing immersion, compression, massage or nutritional strategies against passive rest alone. A further 27 reports measured outcomes unrelated to post-exercise fatigue or performance restoration, most commonly chronic training adaptation or injury incidence. Fourteen reports were conducted in non-athletic, clinical or occupational populations, 12 mentioned active recovery only as an incidental element of a training or testing protocol rather than as an evaluated condition, and 11 were study protocols, reviews or case reports lacking primary comparative data. Seventeen studies satisfied all criteria and were carried forward to quality appraisal and synthesis. The complete flow, with counts and exclusion reasons at each phase, is presented in Figure 1 in accordance with the PRISMA 2020 statement (Page et al., 2021).

Table 3. Summary of the 17 included studies

Title	Author(s), Year and Journal	Design and sample	Key findings
Comparison of 4 Different Cooldown Strategies on Lower-Leg Temperature, Blood Lactate Concentration, and Fatigue Perception After Intense Running	Lim, Park, Lee, & Park (2022); Journal of Sport Rehabilitation	Randomised crossover; 17 healthy young males; 10-min intense treadmill run	Cold-water walking lowered lower-leg muscle temperature most (−11.6 °C), followed by cold-water sitting, passive recovery and active recovery. Blood lactate concentration and fatigue perception did not differ across the four cooldown strategies.
The Effects of "Physical BEMER® Vascular Therapy" on Work Performed During Repeated Wingate Sprints	Fehr, McEwen, & Robinson (2023); Research Quarterly for Exercise and Sport	Randomised crossover; 15 recreationally active adults; four repeated Wingate anaerobic tests	Peak power, average power, fatigue index and total work did not differ between active, passive and BEMER recovery. Active recovery alone produced a significant decline in pain intensity and pain unpleasantness across the recovery period, whereas both comparators showed rising pain ratings.
Effect of subtetanic neuromuscular electrical stimulation on sprint interval exercise	Takeda, Nojima, Nishikawa, & Watanabe (2024); International Journal of Sports Medicine	Randomised crossover; 16 healthy young adults (10 males); four 15-s maximal sprints	Adding subtetanic electrical stimulation to voluntary active cycling recovery raised blood lactate accumulation and produced greater voluntary fatigue, yet mean sprint power and peripheral muscle fatigue were unchanged relative to voluntary cycling alone.
Blood and salivary lactate responses to active rest following circuit exercise	Kojima et al. (2025); Frontiers in Physiology	Randomised crossover; 11 adults (7 males, 4 females); 30-min lower-limb circuit exercise	Active rest produced significantly lower blood lactate (4.2 versus 6.9 mmol/L) and salivary lactate (0.8 versus 3.1 mmol/L) than seated control immediately after the recovery period, and blood and salivary concentrations were strongly correlated during recovery.
The Effect of Active Recovery, Passive Recovery and Sports Massage on Cortisol and Lactate Levels in Semi-professional Male Runners	Davoodi, Hossienzadeh, & Saadat (2023); Sadra Medical Sciences Journal	Semi-experimental two-group comparison; 20 semi-professional male runners; 1500-m race	Cortisol increased significantly from baseline following active recovery, whereas cortisol after massage did not differ from baseline; lactate rose significantly after massage. No significant between-method difference was observed for either cortisol or lactate.
Recovery from Different High-Intensity Interval Training Protocols: Comparing Well-Trained Women and Men	Hottenrott et al. (2021); Sports	Quantitative descriptive repeated-measures; 22 well-trained cyclists and triathletes (11 women, 11 men); four 30-s Wingate tests	With three- and ten-minute active recovery intervals, men exhibited significantly higher lactate concentrations, whereas heart-rate recovery and subjective recovery were significantly slower in women, indicating sex-specific recovery kinetics under identical active recovery doses.
Optimizing active recovery strategies for finger flexor fatigue	Krupková, Tufano, & Baláš (2024); Frontiers in Sports and Active Living	Randomised crossover; climbers; three exhaustive intermittent isometric finger-flexor tests per visit	Impulse declined across trials under all three active recovery modes, but was significantly higher after walking than after hanging or climbing, indicating that active recovery loading the same muscle group as the fatiguing task impairs subsequent localised performance.
Repeatability of the individual response to the use of active recovery the day after high-intensity	Wiewelhove et al. (2021); International Journal of Sports	Double-crossover randomised trial; 11 well-trained male intermittent-sport athletes; four HIIT	High-intensity interval training induced significant fatigue across all markers, but no main effect of recovery strategy was detected. Individual responses to active recovery were

Title	Author(s), Year and Journal	Design and sample	Key findings
interval training: A double-crossover trial	Physiology and Performance	sessions with two-week washouts	inconsistent and non-repeatable in nine of eleven athletes, with only two showing a stable response direction.
The effects of different recovery methods on anaerobic performance in combat sports athletes	Yarar, Gök, Dağtekin, Saçan, & Eroğlu (2021); Acta Gymnica	Randomised crossover across three days; 13 elite international combat-sport athletes; countermovement jump and Wingate testing	Countermovement jump increased significantly after both cold-water immersion and active recovery, whereas the fatigue index improved only after cold-water immersion. Active recovery increased ratings of perceived exertion, and peak and mean power did not differ between conditions.
Comparative evaluation of recovery interventions—individually and in combination—on lactate clearance and physical performance metrics following 3 versus 3 basketball matches	Maan & Yadav (2025); Journal of Bodywork and Movement Therapies	Within-group repeated-measures design; 21 male basketball players aged 18–25 with competitive experience; 3v3 match play	Post-match lactate averaged 10.0 mmol/L and fell to 4.4 mmol/L by 15 minutes. Active recovery combined with foam rolling improved lactate clearance and agility more than active recovery alone or combined with massage, whereas the massage combination favoured explosive strength recovery.
Muscle mechanical response to exercise with active vs. passive rest	Bueno-Russo et al. (2024); Apunts Sports Medicine	Experimental repeated-measures comparison; 90 crawl-stroke swimmers of mean age 20 years; lactic resistance training sessions	Tensiomyographic contractile parameters of pectoralis major, latissimus dorsi and triceps brachii were largely unchanged between lactic resistance training performed with active rest and with passive rest, with isolated differences confined to contraction time and to activation time in latissimus dorsi.
Effectiveness of two different recovery process on blood lactate removal pattern of soccer players	Katoch, Farooque, Dhar, & Das (2025); Pedagogy of Physical Culture and Sports	Crossover comparison on separate days; 10 male junior national soccer players; graded treadmill exercise followed by 5 min at 90% intensity	Blood lactate removal differed significantly between conditions. Active recovery produced peak removal at the fifth and twentieth minutes and 96% clearance at 60 minutes, against 91% for passive recovery, although neither condition restored baseline within one hour.
Acute performance responses to repeated treadmill sprints in hypoxia with varying inspired oxygen fractions, exercise-to-recovery ratios and recovery modalities	Tong, Tao, Chow, Baker, & Jiao (2021); European Journal of Applied Physiology	Randomised repeated-measures trial with seven conditions; 10 male participants; three sets of five 5-s all-out treadmill sprints	Peak and mean sprint velocity were preserved at simulated altitudes to 2500 m under passive recovery. Substituting active for passive recovery at 3500 m produced a mild reduction in mean velocity of 2.6%, indicating that active recovery may compromise sprint quality under hypoxic stress.
Comparative Effectiveness of Active Recovery and Static Stretching During Post-Exercise Recovery in Elite Youth Basketball	Pernigoni et al. (2024); Research Quarterly for Exercise and Sport	Counterbalanced randomised crossover; 17 elite youth male basketball players; two 90-min training sessions	No significant differences emerged between active recovery and static stretching at any matched time point. Countermovement jump was depressed post-recovery in the stretching condition only, whereas heart-rate variability failed to return to baseline and perceived recovery was impaired in the active recovery condition only.
The effect of acute sleep extension vs active recovery on post exercise recovery kinetics in rugby union players	Leduc et al. (2022b); PLoS ONE	Randomised crossover; 10 male rugby union players; two evening collision-based training sessions seven days apart	Sleep extension produced faster recovery of cognitive performance at 14 hours post-training, whereas the active recovery condition showed superior autonomic function and upper-body neuromuscular function at the same time point. No between-

Title	Author(s), Year and Journal	Design and sample	Key findings
			condition difference in recovery status remained at 36 hours.
Active recovery vs hot- or cold-water immersion for repeated sprint ability after a strenuous exercise training session in elite skaters	Solsona et al. (2023); Journal of Sports Sciences	Randomised crossover; 12 national-team skaters (7 males, 5 females); exhaustive ice-skating session followed by repeated-sprint cycling	Average power output was significantly higher after active recovery and hot-water immersion than after cold-water immersion. Lactatemia, perceived exertion and the fatigue index did not differ between conditions, and mean muscle temperature during recovery correlated positively with subsequent maximal power.
The acute effect of proprioceptive neuromuscular facilitation recovery technique on fatigue in karate athletes	Arovah & Putri (2024); Science and Sports	2 × 2 factorial design; 60 karate athletes (50% male); 60-min submaximal karate-specific exercise	Heart rate, perceived exertion and total quality recovery improved significantly from pre- to post-test in all groups. Post-test perceived exertion and perceived recovery were significantly better under the active recovery condition, whereas heart rate showed no advantage over passive recovery.

Note. All bibliographic details, titles, designs and reported findings are drawn from the source records retrieved in the Scopus search. Author affiliation country was not available in the exported metadata and is therefore not reported.

Table 4. Classification of included studies by population, design, theme, active recovery protocol and outcome

Author(s), Year	Population and sport context	Research design	Theme / focus	Active recovery protocol	Outcome measures
Lim, Park, Lee, & Park (2022)	Recreationally active young males (running)	Randomised crossover	Metabolic clearance and thermal response	Active recovery: 10-min treadmill walk plus 10-min static stretching plus 10-min shower (30 min total)	Muscle temperature; blood lactate; fatigue perception
Fehr, McEwen, & Robinson (2023)	Recreationally active adults (cycle ergometry)	Randomised crossover	Anaerobic performance and perceptual response	Active recovery: 4 min pedalling at 50 rpm at 20% of sprint workload between sprints	Peak and average power; fatigue index; work; pain intensity and unpleasantness
Takeda, Nojima, Nishikawa, & Watanabe (2024)	Healthy young adults (sprint interval cycling)	Randomised crossover	Augmented active recovery and metabolic load	Active recovery: 5-min voluntary cycling at 40% of peak oxygen consumption, with or without superimposed subtetanic NMES	Blood lactate; mean power; maximal voluntary contraction of knee extensors
Kojima et al. (2025)	Physically active adults (circuit exercise)	Randomised crossover	Metabolic clearance and non-invasive monitoring	Active recovery: 15 min of light cycling immediately after the circuit bout	Blood lactate; salivary lactate
Davoodi, Hossienzadeh, & Saadat (2023)	Semi-professional male runners	Semi-experimental two-group comparison	Endocrine and metabolic response	Active recovery applied immediately after a competitive 1500-m race, compared with sports massage	Serum cortisol; blood lactate
Hottenrott et al. (2021)	Well-trained female and	Quantitative descriptive	Dose of active recovery and sex differences	Active recovery intervals of 1, 3 or 10 min	Blood lactate; heart rate; oxygen uptake; perceived exertion

Author(s), Year	Population and sport context	Research design	Theme / focus	Active recovery protocol	Outcome measures
	male cyclists and triathletes	repeated-measures		interposed between repeated Wingate tests	and perceived recovery
Krupková, Tufano, & Baláš (2024)	Climbers (localised upper-limb fatigue)	Randomised crossover	Muscle-group specificity of active recovery	22 min of active recovery allocated as walking, intermittent hanging, or easy climbing	Impulse of intermittent isometric finger-flexor contractions
Wiewelhove et al. (2021)	Well-trained male intermittent-sport athletes	Double-crossover randomised trial	Individual responsiveness and repeatability	Active recovery: 60 min of moderate cycling performed 24 h after the HIIT session, versus passive recovery	Maximal voluntary isometric contraction; countermovement jump; tensiomyography; creatine kinase; muscle soreness; perceived stress
Yarar, Gök, Dağtekin, Saçan, & Eroğlu (2021)	Elite combat-sport athletes	Randomised crossover across three days	Comparative modality effectiveness in congested competition	Active recovery administered between successive testing sessions, versus passive recovery and cold-water immersion	Countermovement jump; fatigue index; peak and mean power; body temperature; perceived exertion
Maan & Yadav (2025)	Male basketball players	Within-group repeated-measures design	Combined modalities and individual variability	Active recovery administered alone and in combination with massage therapy or foam rolling after 3v3 matches	Blood lactate; sprint performance; explosive strength; agility
Bueno-Russo et al. (2024)	Competitive crawl-stroke swimmers	Experimental repeated-measures comparison	Neuromuscular contractile response	Lactic resistance training sessions performed with active rest versus passive rest between efforts	Tensiomyographic activation time, contraction time and maximal radial displacement
Katoch, Farooque, Dhar, & Das (2025)	Male junior national soccer players	Crossover comparison on separate days	Metabolic clearance kinetics	Low-intensity active recovery on a treadmill versus passive rest, with lactate sampled to 60 min	Blood lactate removal pattern and percentage clearance
Tong, Tao, Chow, Baker, & Jiao (2021)	Male participants in simulated hypoxia (repeated-sprint running)	Randomised repeated-measures trial with seven conditions	Environmental moderation of active recovery	Recovery modality switched from passive to active within a 1:5 exercise-to-recovery ratio at 3500 m	Peak and mean velocity; velocity decrement score; cumulative training impulse
Pernigoni et al. (2024)	Elite youth male basketball players	Counterbalanced randomised crossover	Comparative modality effectiveness and autonomic response	Active recovery versus static stretching administered immediately after a 90-min training session	Countermovement jump; Ln-rMSSD; muscle soreness; total quality recovery; cortisol and testosterone

Author(s), Year	Population and sport context	Research design	Theme / focus	Active recovery protocol	Outcome measures
Leduc et al. (2022b)	Male rugby union players	Randomised crossover	Comparative modality effectiveness across recovery domains	Early-morning active recovery session at 07:30 versus extension of sleep to 10 hours	Countermovement jump mean power; wellness; heart-rate recovery; cognitive performance; objective sleep parameters
Solsona et al. (2023)	National-team ice skaters	Randomised crossover	Comparative modality effectiveness and thermal mechanism	15 min of active recovery versus 20 min hot-water immersion or 15 min cold-water immersion between sessions	Average and maximal power output; lactatemia; perceived exertion; fatigue index; muscle temperature
Arovah & Putri (2024)	Male and female karate athletes	2 × 2 factorial design	Perceptual recovery and movement-based active recovery	2.5 min of light-intensity proprioceptive neuromuscular facilitation within a 15-min active recovery period, versus passive recovery	Heart rate; rating of perceived exertion; total quality recovery

Descriptive Characteristics

The 17 included studies were published between 2021 and 2025, with four appearing in 2021, two in 2022, three in 2023, five in 2024 and three in 2025. Output was therefore broadly stable across the review window rather than accelerating, which suggests a mature rather than emergent research area. All included reports were peer-reviewed journal articles. The corpus is dispersed across 16 distinct journals, with only Research Quarterly for Exercise and Sport contributing two reports, indicating that active recovery research is distributed across general sport science, applied physiology, rehabilitation and bodywork outlets rather than concentrated in a specialist venue. Sample sizes were characteristically small: eleven studies enrolled 20 participants or fewer, the median sample comprised approximately 15 participants, and only two studies exceeded 50 participants. Six studies included female participants, of which three reported sex-disaggregated analyses. The full bibliographic and methodological characteristics of each study are reported in Table 3, and the classification by population, design, theme, protocol and outcome is reported in Table 4.

Design distribution favoured within-participant comparison. Nine studies used a randomised crossover architecture, four used non-randomised repeated-measures or semi-experimental comparisons, one used a double-crossover design with two-week washouts, one used a factorial allocation, one used a within-group repeated-measures structure and one was quantitative descriptive. The annual distribution of studies by design category is presented in Figure 2. The predominance of crossover designs is methodologically appropriate given the small samples available in elite populations, but it also concentrates the corpus within acute observation windows: fourteen studies observed recovery for two hours or less, and only three extended observation to 24 hours or beyond.

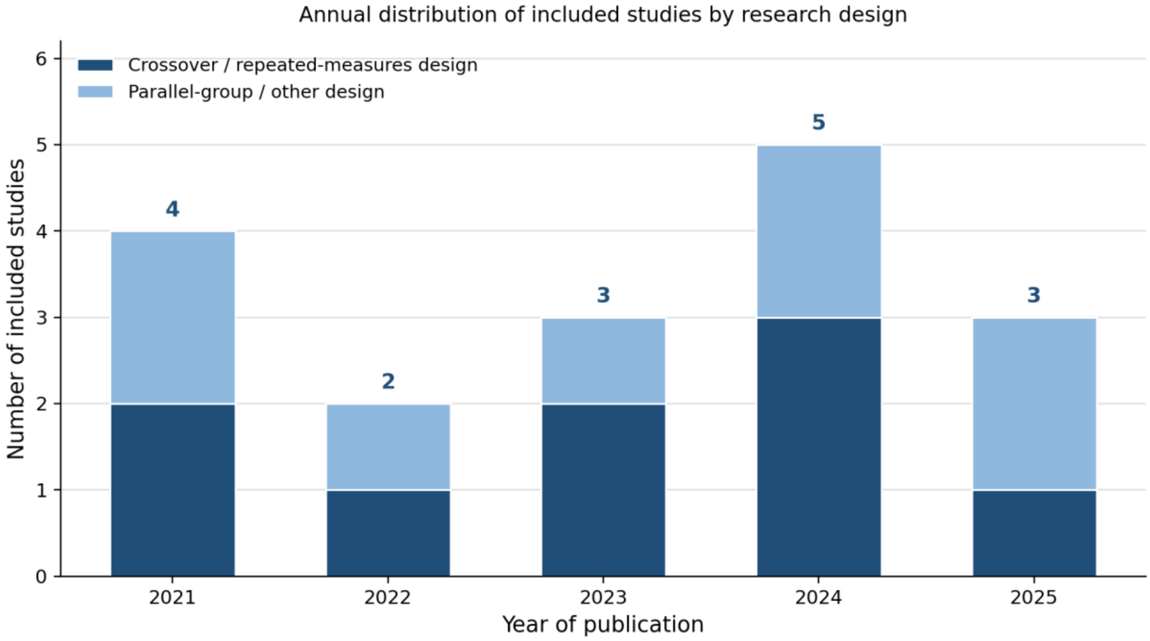

Figure 2. Annual distribution of the 17 included studies by research design (2021–2025).

The corpus spans a broad range of sport disciplines and population contexts. Five studies were conducted with recreationally active or physically active adults in laboratory settings, two with soccer players, two with basketball players, two with combat-sport athletes, two in cycling and triathlon contexts, two in running and endurance settings, and two in ice sports, rugby and swimming. This distribution, shown in Figure 3, indicates that the evidence base is weighted towards controlled laboratory conditions and intermittent team sports, with comparatively limited representation of endurance-dominant and technical-aesthetic disciplines. As stated in Section 3.7, author affiliation country was not recoverable from the exported metadata, so no geographic distribution is reported; the distributional analysis is instead organised by discipline and population context, both of which are documented within the source reports.

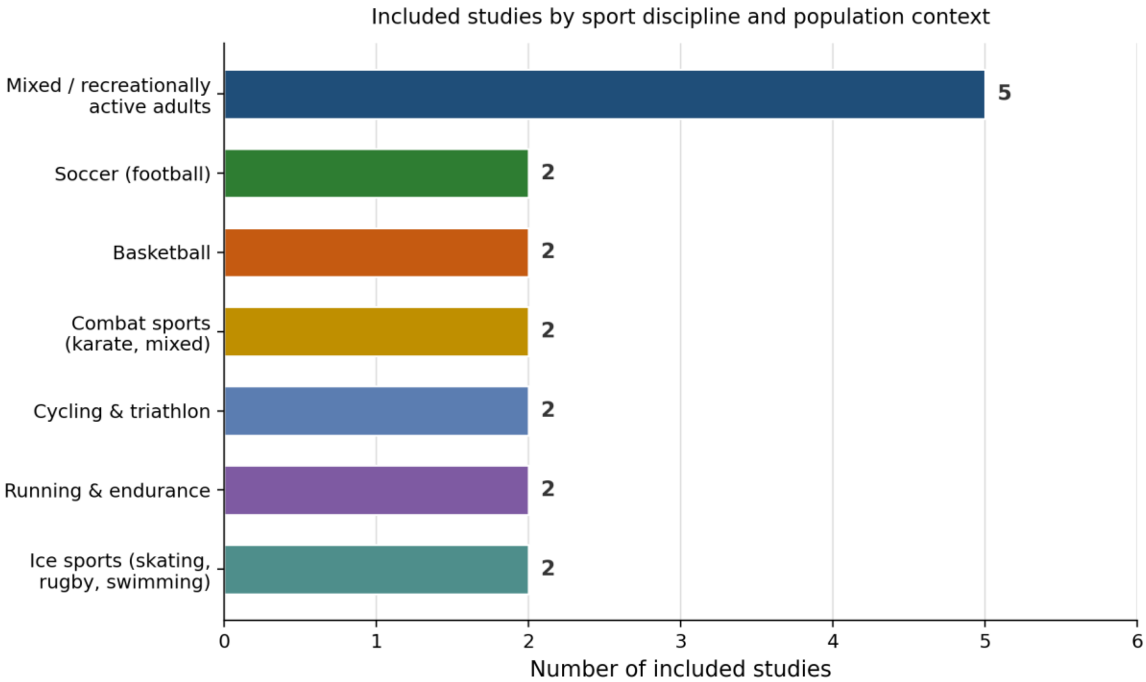

Figure 3. Distribution of the included studies by sport discipline and population context.

Keyword co-occurrence analysis corroborates the construct boundaries of the corpus. Four thematic clusters emerged. The physiological fatigue-marker cluster is anchored by lactic acid, fatigue, muscle fatigue, oxygen consumption, heart rate and hydrocortisone; the modality and stimulus cluster by active recovery, immersion, exercise, running, basketball and high-intensity interval training; the outcome and design cluster by athletic performance, controlled study and randomised controlled trial; and the population cluster by male, female, adult, young adult and adolescent. The predominance of male over female as an indexed population descriptor, visible in Figure 4, provides an independent signal of the sex imbalance noted above.

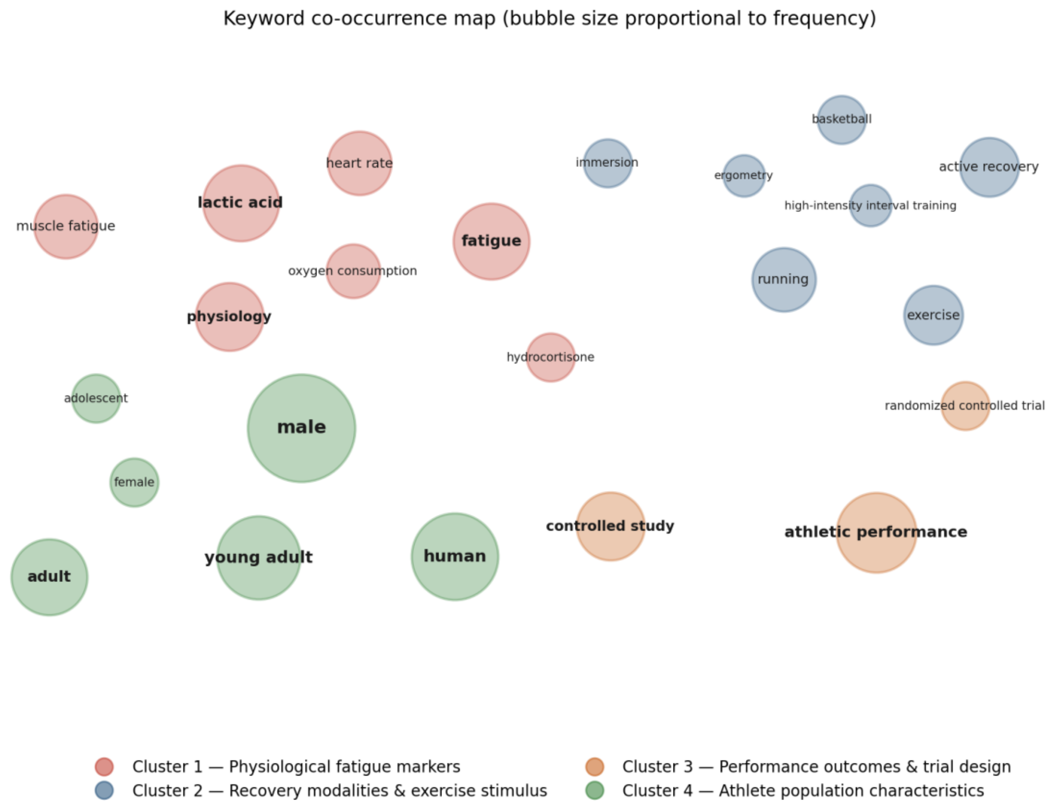

Figure 4. Keyword co-occurrence map of the 17 included studies, with bubble diameter proportional to term frequency.

Thematic Synthesis

Findings for RQ1: Active recovery and physiological markers of fatigue

The most consistent physiological signal across the corpus concerns metabolite clearance. Katoch et al. (2025) reported a significant between-condition difference in blood lactate removal in junior national soccer players, with active recovery producing earlier removal peaks at the fifth and twentieth minutes and higher cumulative clearance at 60 minutes than passive recovery. Kojima et al. (2025) observed the same directional effect under laboratory conditions, with light cycling producing markedly lower blood and salivary lactate concentrations than seated rest immediately after the recovery period. The convergence of these findings across different fatiguing stimuli, sampling schedules and populations lends the clearance effect a degree of robustness uncommon elsewhere in the corpus. Its magnitude, however, warrants caution. Katoch et al. (2025) reported that neither condition restored baseline lactate within one hour, and their logistic model reached significance only at the 0.10 level, indicating that the advantage of active recovery is one of kinetics rather than of completeness.

The clearance effect is nevertheless neither universal nor unconditional. Lim et al. (2022) found no difference in blood lactate concentration among four cooldown strategies including active recovery, cold-water walking, cold-water sitting and passive recovery, despite pronounced between-condition differences in lower-leg muscle temperature. Solsona et al. (2023) similarly reported no differences in lactatemia among active recovery, hot-water immersion and cold-water immersion in national-team skaters. Two features distinguish these null findings from the positive ones. First, both employed multi-modality comparators rather than a passive control, so the relevant contrast is between active alternatives rather than between activity and rest. Second, both sampled lactate after relatively prolonged recovery windows, by which point spontaneous clearance may have compressed between-condition differences. Taken together, the corpus supports the conclusion that active recovery accelerates lactate removal relative to passive rest, but confers no reliable metabolic advantage over other physiologically active modalities.

Evidence for other physiological markers is markedly weaker and in places contrary. Davoodi et al. (2023) found that serum cortisol increased significantly from baseline following active recovery in semi-professional runners, while cortisol following massage did not, with no significant between-method difference for either cortisol or lactate; the direction of the cortisol response indicates that active recovery may extend rather than attenuate the endocrine stress response after maximal effort. Wiewelhove et al. (2021) measured creatine kinase, tensiomyographic markers and muscle soreness after high-intensity interval training and detected no main effect of recovery strategy on any of them. Bueno-Russo et al. (2024) reported that contractile properties of the principal propulsive muscles in swimmers were essentially unchanged between active and passive rest, with differences confined to isolated contraction- and activation-time parameters. Autonomic markers behaved unexpectedly: Pernigoni et al. (2024) found that heart-rate variability failed to return to baseline after active recovery, though not after static stretching. The pattern is therefore domain-specific. Active recovery acts on the metabolite compartment, exerts little measurable influence on markers of structural muscle damage, and may transiently prolong endocrine and autonomic activation.

Findings for RQ2: Comparative performance restoration

Across the corpus, the modal finding for performance outcomes is equivalence. Fehr et al. (2023) found no differences in peak power, average power, fatigue index or total work between active, passive and vascular-therapy recovery interposed between repeated Wingate tests. Pernigoni et al. (2024) reported no significant differences between active recovery and static stretching at any matched time point in elite youth basketball players and concluded that neither strategy meaningfully improved post-exercise recovery. Bueno-Russo et al. (2024) reached a comparable conclusion for neuromuscular contractile response in swimmers. Wiewelhove et al. (2021) observed no main effect of active recovery on maximal voluntary isometric contraction or countermovement jump 24 and 48 hours after high-intensity interval training. Four studies employing different populations, fatigue protocols and outcome batteries thus converge on the same null.

Where differences do emerge, they are small, context-bound and not uniformly favourable to active recovery. Solsona et al. (2023) found average power output to be significantly higher after active recovery and hot-water immersion than after cold-water immersion, with a small effect size, and attributed the difference to preserved muscle temperature rather than to metabolic recovery. Yarar et al. (2021) reported that countermovement jump improved after both cold-water immersion and active recovery in elite combat-sport athletes, but that the fatigue index improved only after immersion. Maan & Yadav (2025) found that active recovery combined with foam rolling outperformed active recovery alone and active recovery with massage for lactate clearance and agility, while the massage combination proved superior for explosive strength, indicating that the benefit resides in the combination rather than in the active component alone. Leduc et al. (2022b) found active recovery superior to sleep extension for autonomic and upper-body neuromuscular function at 14 hours, but inferior for cognitive recovery, with all differences dissipating by 36 hours.

Two studies report performance decrements associated with active recovery. Tong et al. (2021) found that replacing passive with active recovery during repeated treadmill sprinting at a simulated altitude of 3500 m produced a mild reduction in mean velocity of 2.6%, which is a small but non-trivial cost in a repeated-sprint context. Krupková et al. (2024) found that active recovery involving the fatigued musculature, whether through intermittent hanging or easy climbing, produced significantly lower subsequent impulse than walking, which loads a different muscle group entirely. Read alongside the finding of Takeda et al. (2024) that augmenting active cycling recovery with electrical stimulation increased both blood lactate and voluntary fatigue without improving sprint output, these results indicate that active recovery carries a dose-dependent metabolic cost that can offset or exceed its clearance benefit. The answer to RQ2 is therefore that active recovery is not comparatively superior for performance restoration; it is broadly equivalent to alternative modalities, and under specific conditions it is inferior.

Findings for RQ3: Moderators of active recovery effectiveness

Four moderators are identifiable within the corpus. The first is muscle-group specificity. Krupková et al. (2024) demonstrated directly that active recovery loading the fatigued musculature impairs subsequent localised performance relative to active recovery that engages an unfatigued segment, which reframes active recovery as a targeted rather than generic prescription. The second is dose. Hottenrott et al. (2021) manipulated active recovery duration systematically across intervals of one, three and ten minutes and demonstrated that recovery kinetics diverge as a function of interval length, while Takeda et al. (2024) showed that increasing the metabolic demand of the recovery bout itself elevates lactate accumulation and voluntary fatigue. Dose is therefore not a neutral implementation detail but a determinant of direction of effect.

The third moderator is environmental and thermal context. Tong et al. (2021) established that hypoxic stress converts a neutral intervention into a mildly detrimental one, and Solsona et al. (2023) identified muscle temperature during recovery as a positive correlate of subsequent maximal power, which situates the active recovery advantage over cold-water immersion within a thermal rather than a metabolic mechanism. Lim et al. (2022) reinforce this reading by showing large between-condition differences in muscle temperature alongside no differences in lactate or fatigue perception. The fourth moderator is individual responsiveness. Wiewelhove et al. (2021) tested repeatability directly using a double-crossover design and found that nine of eleven athletes displayed inconsistent, non-repeatable responses to active recovery, with only two showing a stable response direction. Maan & Yadav (2025) independently emphasised individual variability in their conclusion. Together these findings imply that group-level nulls may mask heterogeneous individual effects that cancel in aggregate, and that responder identification is a methodological prerequisite rather than a refinement.

A fifth and less firmly established moderator concerns participant sex. Hottenrott et al. (2021) found that men displayed higher lactate concentrations after three- and ten-minute active recovery intervals while women showed slower heart-rate and subjective recovery, and Arovah & Putri (2024) reported a significant sex effect for post-test perceived exertion in karate athletes. With only three sex-disaggregated analyses in the corpus, this moderator is signalled rather than established, and it constitutes one of the clearest priorities for future work.

Comparative and Critical Analysis

Methodologically, the corpus is dominated by acute within-participant designs. Nine of 17 studies used randomised crossover allocation and a further four used non-randomised repeated-measures comparison, a distribution that maximises statistical efficiency in small elite samples but restricts inference to the immediate post-exercise window. Fourteen studies confined observation to two hours or less, and only Wiewelhove et al. (2021), Leduc et al. (2022b) and Pernigoni et al. (2024) extended measurement to 24 hours or beyond. This temporal concentration is consequential, because the outcome on which active recovery performs best, blood lactate, normalises within the observation window of nearly every study, whereas the outcomes on which it performs least well, neuromuscular function and muscle damage markers, resolve over a longer horizon. The apparent efficacy of active recovery is therefore partly an artefact of measurement timing.

Comparator selection is a second axis of methodological variability with direct interpretive consequences. Studies employing passive rest as the sole comparator, including Katoch et al. (2025) and Kojima et al. (2025), report positive findings for active recovery. Studies employing physiologically active comparators such as immersion, stretching, massage or sleep extension, including Lim et al. (2022), Pernigoni et al. (2024), Solsona et al. (2023) and Leduc et al. (2022b), predominantly report equivalence. The apparent contradiction between these two groups substantially dissolves once comparator strength is taken into account, which suggests that the field's disagreement about active recovery is in part a disagreement about the counterfactual.

Underused designs are equally informative. Only one study, Wiewelhove et al. (2021), employed a repeated-measures architecture capable of estimating the repeatability of individual responses, and its finding of non-repeatability in nine of eleven athletes casts retrospective doubt on the interpretability of single-exposure crossover nulls throughout the corpus. Dose-response designs are represented only by Hottenrott et al. (2021), and no study in the corpus randomised participants to graded active recovery intensities while holding duration constant. Longitudinal designs that track cumulative effects across a training block are entirely absent. Sample sizes are small, with a median of approximately 15 participants and eleven studies at 20 or fewer, which leaves most trials underpowered to detect the modest effects the corpus itself suggests are plausible.

A sensitivity analysis was conducted in accordance with the weighting procedure specified in Section 3.6. One study, Davoodi et al. (2023), scored 3.0 on the MMAT and was flagged as being of lower methodological confidence, principally because participant allocation and confounder control were incompletely reported. Excluding this study from the synthesis does not alter any thematic conclusion: the metabolic clearance finding for RQ1 rests on Katoch et al. (2025) and Kojima et al. (2025); the endocrine observation to which Davoodi et al. (2023) contributes is presented as a single-study signal rather than as a synthesised finding; and no conclusion regarding RQ2 or RQ3 draws upon it. The remaining 16 studies scored 4.0 or above and were classified as high quality, with the most frequent partial score concerning incomplete reporting of blinding or of the completeness of outcome data.

The principal interpretive contribution of this synthesis is the decoupling of metabolite clearance from functional restoration. The evidence supports the classical physiological rationale for active recovery insofar as sustained low-intensity activity maintains perfusion and accelerates lactate removal (Katoch et al., 2025; Kojima et al., 2025), yet the same corpus shows that this metabolic advantage does not propagate to neuromuscular performance (Bueno-Russo et al., 2024; Fehr et al., 2023; Pernigoni et al., 2024; Wiewelhove et al., 2021). This dissociation is theoretically consequential because it undermines the implicit inferential chain by which lactate clearance has long been treated as a proxy for readiness. It converges with the broader recognition that fatigue is a multidimensional construct whose components recover on distinct timescales (Gavanda et al., 2023; Ostapiuk-Karolczuk et al., 2025) and with monitoring research demonstrating systematic divergence between subjective and objective readiness indices (Simonelli et al., 2025).

Theoretically, the findings extend contemporary accounts of recovery in two directions. First, they support a compartmental model in which metabolic, structural, autonomic and perceptual dimensions of fatigue are addressed by different modalities rather than by a single general-purpose intervention, consistent with evidence that immersion acts on central and peripheral fatigue components (Bouchiba et al., 2022) while mechanical modalities act on soreness and tissue compliance (Abdulkader et al., 2025; Corredoira et al., 2025). Second, the demonstration by Krupková et al. (2024) that active recovery is muscle-group specific challenges the systemic framing that has dominated the literature and aligns recovery theory with the locality principles already established in resistance-training and neuromuscular research (Mur-Gimeno et al., 2022; Sedano & Maroto-Izquierdo, 2025). The observation by Solsona et al. (2023) that muscle temperature correlates with subsequent power adds a thermal pathway that partially explains why active recovery outperforms cold-water immersion in the immediate pre-performance window.

Practically, three implications follow for coaches and applied practitioners. Active recovery should be prescribed where accelerated metabolite clearance within a short interval is the operative objective, such as between bouts within a session or between matches on a single competition day, a context in which the combat-sport findings of Yarar et al. (2021) and the basketball findings of Maan & Yadav (2025) are directly applicable. It should not be prescribed on the expectation of restoring neuromuscular performance, for which the evidence is null. And it should be dosed conservatively and directed away from the fatigued musculature, because the reports of Krupková et al. (2024), Takeda et al. (2024) and Tong et al. (2021) collectively establish that an excessive or misdirected active recovery load can impose an additional metabolic burden. These recommendations are consistent with the integration of recovery into structured periodisation reported in applied programmes (Vachon et al., 2022; Younger & Cochrane, 2024; Wiewelhove et al., 2024) and with the multimodal protocols increasingly deployed in team-sport settings (Aben et al., 2023; Brini et al., 2025).

Situated against prior reviews and applied syntheses, the present findings temper an optimistic consensus. Practice surveys report high prevalence and high perceived effectiveness of active recovery among endurance athletes, triathletes and team-sport practitioners (Daly et al., 2024; Field et al., 2022; Finlay et al., 2022; Leabeater et al., 2022; Li et al., 2025), and applied overviews continue to position it as a core component of recovery programming (George et al., 2025). The comparative experimental evidence assembled here does not support that positioning for performance outcomes. A similar gap between perceived and demonstrated efficacy has been documented for other widely adopted modalities, including cold-water immersion in elite football (Alexander et al., 2022a), cryo-compression (Alexander et al., 2022b), blood flow restriction (Castilla-López & Romero-Franco, 2023), manual massage after high-intensity interval training (Avandi et al., 2024) and hyperbaric oxygen therapy (Gušić et al., 2024), which suggests a field-wide tendency for adoption to outpace evidence.

Several contradictions within the literature merit explicit attention. The metabolic findings of Katoch et al. (2025) and Kojima et al. (2025) stand against the nulls of Lim et al. (2022) and Solsona et al. (2023), a discrepancy attributable principally to comparator strength and sampling timing as argued in Section 5.4. The endocrine finding of Davoodi et al. (2023), in which cortisol rose after active recovery, sits uneasily with the assumption that active recovery attenuates stress responses, and may reflect the intensity of the preceding 1500-m maximal effort rather than a property of the intervention. The autonomic finding of Pernigoni et al. (2024), in which heart-rate variability failed to normalise after active recovery but did so after stretching, is similarly counter-intuitive and consistent with a residual sympathetic activation cost. Most fundamentally, the non-repeatability demonstrated by Wiewelhove et al. (2021) suggests that some apparent contradictions across studies are not contradictions at all, but samplings of a heterogeneous individual response distribution.

Three research gaps follow directly. The first is the absence of dose-response evidence: no study randomised participants to graded active recovery intensities while holding modality and duration constant, so the field cannot specify a prescription beyond the descriptive label low-intensity. The second is the near-absence of longitudinal evidence: the corpus contains no study tracking the cumulative effect of habitual active recovery across a training block or competitive season, leaving the relationship between acute equivalence and chronic adaptation entirely unexamined. The third is the underdevelopment of responder-level analysis: only one study estimated individual response repeatability, and no study attempted to characterise the physiological or anthropometric profile of consistent responders.

This review has at least four limitations. It relied on a single database, Scopus, without supplementary searching of MEDLINE, SPORTDiscus, Web of Science, trial registers or grey literature, and without citation chasing, so relevant reports indexed elsewhere may have been missed. It restricted inclusion to English-language articles, which introduces a language bias of particular concern in a field with substantial regional publication in other languages. It did not register a protocol prospectively, which limits protection against post hoc modification of the eligibility criteria. And it synthesised findings narratively rather than statistically, a decision justified by heterogeneity but one that precludes effect-size estimation and formal assessment of publication bias. A further constraint is that author affiliation country was unavailable in the exported metadata, so no geographic analysis of the evidence base could be performed.

The future research agenda that follows is concrete. First, dose-response trials should randomise athletes to active recovery at defined percentages of maximal aerobic power, for instance 30%, 45% and 60%, with duration and modality held constant and with both metabolic and neuromuscular outcomes measured to 48 hours; the interval manipulation of Hottenrott et al. (2021) provides a design template. Second, longitudinal cluster trials should compare habitual active recovery against passive or multimodal alternatives across a full competitive mesocycle, using the periodised architectures already demonstrated to be feasible (Younger & Cochrane, 2024) and outcomes including accumulated training load, wellness and injury exposure (Da Silva et al., 2021; Trecroci et al., 2021). Third, adequately powered responder-identification studies should employ repeated double-crossover exposures following the protocol of Wiewelhove et al. (2021) with samples sufficient to characterise consistent responders and non-responders. Fourth, and cutting across all three, trials should recruit and analyse female athletes in sufficient numbers to test the sex-specific recovery kinetics signalled by Hottenrott et al. (2021) and Arovah & Putri (2024).

In summary form, the three research questions are answered as follows. RQ1: active recovery significantly accelerates blood and salivary lactate clearance relative to passive rest, but exerts no reliable effect on creatine kinase, muscle soreness or tensiomyographic markers, and may transiently elevate cortisol and delay the normalisation of heart-rate variability. RQ2: active recovery is not superior to alternative modalities for restoring physical performance; the modal outcome is equivalence, small advantages over cold-water immersion appear attributable to preserved muscle temperature, and performance decrements arise under hypoxia and when the recovery activity loads the fatigued musculature. RQ3: effectiveness is moderated by muscle-group specificity, by dose, by environmental and thermal context, and by substantial and largely non-repeatable individual variation, with participant sex a probable but not yet established additional moderator.

Conclusion

This review synthesised 17 comparative experimental studies and found that active recovery reliably accelerates blood and salivary lactate clearance relative to passive rest, yet exerts no dependable influence on muscle damage markers, and that it is not superior to stretching, immersion, massage or sleep extension for restoring physical performance, with equivalence the modal outcome and decrements arising under hypoxic conditions or when the recovery activity loads the fatigued musculature. Its effectiveness is moderated by muscle-group specificity, dose, thermal context and pronounced individual variability. The core contribution of the review is to decouple metabolite clearance from functional restoration, which invalidates the common inference from lactate removal to readiness. Practitioners should therefore prescribe active recovery for short between-bout intervals rather than for neuromuscular restoration. Conclusions are constrained by single-database searching, English-language restriction and predominantly acute observation windows. Dose-response, longitudinal and responder-identification trials, with adequate representation of female athletes, are now required.

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