



Integrative sport medicine rehabilitation for early-onset knee osteoarthritis in overweight young adults: Evidence from meta-analytic reviews



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ABSTRACT

Background: Early-onset and early-stage knee osteoarthritis (KOA) is increasingly reported in overweight young adults and is associated with pain, functional limitations, and reduced quality of life. This umbrella review aims to map the domains of Sports Medicine-Oriented Holistic Rehabilitation (SMOHR) interventions, defined as exercise-based therapy combined with at least one additional domain, and to summarize the reported effects and certainty of evidence for pain, physical function, psychosocial outcomes, and quality of life.

Methods: A PRISMA 2020-guided search of PubMed, Scopus, Web of Science, and SPORTDiscus identified English-language systematic reviews with meta-analyses and network meta-analyses published between 2021 and 2025. Two reviewers independently screened abstracts and full texts; disagreements were resolved through discussion and review by a third reviewer. Review quality was assessed using AMSTAR-2, and GRADE ratings were summarized according to those reported in the included reviews without repeating assessments.

Results: Fifteen meta-analyses were included. Exercise-based rehabilitation was consistently associated with improvements in pain and physical function, although effect estimates varied depending on the comparison and outcome measured. Network meta-analyses also showed favorable comparative performance of knee braces and hydrotherapy for WOMAC-related outcomes; however, subgroup estimates specific to young adults with overweight were rarely reported. Self-management and psychosocial interventions showed more variable effects, with some evidence of benefits for physical activity, pain, and kinesiophobia in specific contexts.

Conclusion: SMOHR may be a useful framework for organizing multiple conservative treatments for KOA, but heterogeneity and limited evidence based on age and BMI limit conclusions for young adults with overweight and early-stage disease. stages.

Keywords: biopsychosocial, knee osteoarthritis, multicomponent rehabilitation, overweight, umbrella review.

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INTRODUCTION

Knee osteoarthritis (KOA) is a common musculoskeletal disorder and a leading cause of pain and functional impairment. Evidence synthesis in recent years shows that KOA is increasingly recognized not only in the elderly population but also in young adults and those who are overweight, with potential consequences for long-term function and quality of life.¹ Excess weight can contribute to KOA through mechanical and biological pathways. Mechanically, higher body weight increases knee joint load and

can alter lower extremity biomechanics. Biologically, metabolic and inflammatory processes associated with obesity are linked to changes in osteoarthritis and symptom burden.²⁻⁵ However, management strategies provided as a single component do not consistently result in sustained improvements in patient outcomes and needs, especially when compliance barriers and lifestyle factors are prominent.^{6,7} Consequently, integrative rehabilitation approaches aligned with sport and exercise medicine have been proposed to combine exercise-based therapy with complementary domains

such as education/self-management, lifestyle or weight-related strategies, and psychosocial support.^{8,9} Conceptually, such multicomponent care is consistent with holistic and biopsychosocial rehabilitation frameworks, which emphasize that recovery is shaped not only by biomechanical restoration but also by psychological factors, behavior, and context.^{9,10}

Although meta-analytic evidence supports conservative rehabilitation options for KOA—particularly exercise-based interventions and related non-pharmacological modalities important

uncertainty remains about how best to structure multicomponent models for overweight young adults with early-stage or early-onset KOA. Many meta-analyses pool heterogeneous OA populations across wide age ranges and disease stages, and subgroup-specific reporting for younger age or overweight status is not consistently available.^{7,11,12} In addition, recent evidence has not been synthesized in a structured manner to map the core components of integrative rehabilitation packages while concurrently relating intervention effects to the certainty and quality of the underpinning reviews.^{7,13}

In this umbrella review, Sport-Medicine-Oriented Holistic Rehabilitation (SMOHR) is used as an operational framework to organize multicomponent, non-pharmacological rehabilitation for KOA. SMOHR is not positioned as a new treatment modality; rather, it is a synthesis framework integrating biomechanical training and exercise-based rehabilitation, metabolic and lifestyle strategies relevant to overweight populations, and psychosocial support and self-management components aimed at improving adherence and addressing pain-related behaviors.^{6,7,14}

This topic is also relevant for low- and middle-income settings, including Indonesia, where overweight prevalence is increasing and access to coordinated rehabilitation pathways may be limited, increasing the need for evidence-informed and scalable models (15). Accordingly, this umbrella review synthesizes systematic reviews and meta-analyses published between 2021 and 2025 to identify the core components and intervention domains of SMOHR-aligned rehabilitation programs relevant to overweight young adults with early-stage KOA and summarize effects on pain, physical function, psychosocial outcomes, and quality of life, including the certainty of evidence as reported in the included reviews.^{6,7,11–14,16}

METHODS

This study was designed as an umbrella review (a systematic review of systematic reviews and meta-analyses) and was reported in accordance with the PRISMA 2020 statement. The review synthesized meta-analytic evidence on

multicomponent, non-pharmacological rehabilitation approaches relevant to overweight young adults with early-stage or early-onset knee osteoarthritis (KOA).

Eligibility criteria

Eligible records were systematic reviews with meta-analysis and network meta-analyses published in English between 2021 and 2025. Reviews were included if they evaluated multicomponent conservative rehabilitation for KOA (or mixed hip/knee osteoarthritis when KOA-specific findings were reported) and reported clinically relevant outcomes. Multicomponent rehabilitation was operationally defined as programs integrating exercise-based therapy (e.g., therapeutic exercise, strengthening, neuromuscular or activity-based rehabilitation) with at least one additional domain (e.g., education/self-management, lifestyle or weight-related strategies, psychosocial or behavioral support, or coordinated multidisciplinary rehabilitation).

Reviews were excluded if they primarily addressed advanced-stage osteoarthritis, postoperative or surgical management, or preclinical/animal research; evaluated single-component interventions without an integrative rehabilitation framework; failed to report clinically relevant outcomes; or provided insufficient information for data extraction.

Outcomes

The primary outcomes were pain and physical function, commonly assessed using WOMAC subscales or other validated pain and function measures. Secondary outcomes included quality of life, kinesiophobia, and other psychosocial measures, gait or performance outcomes, and other functional indicators when available. Biomarkers (e.g., inflammatory markers) were treated as secondary outcomes and were summarized only when reported within the included meta-analytic reviews.

Information sources and search strategy

A systematic search was conducted in PubMed, Scopus, Web of Science, and SPORTDiscus using combinations of keywords related to knee osteoarthritis, early-stage/early-onset osteoarthritis,

multicomponent rehabilitation, sport medicine rehabilitation, exercise therapy, lifestyle/weight management, psychosocial support, and quality of life. The search was restricted to full-text, English-language publications from 2021 to 2025. The complete database-specific search strategy is provided in the Supplementary Material.

Study selection and data extraction

The selection of studies was conducted in two stages: screening of titles/abstracts followed by assessment of full-text eligibility. Two reviewers independently screened the records and assessed eligibility. Discordance was resolved through discussion and, if necessary, determination by a third reviewer. The selection process is summarized in the PRISMA flow diagram.

Data were extracted using a standardized form covering review characteristics (year of publication, review design, number of clinical trials/participants included, osteoarthritis population), intervention domain, comparison, outcome, effect estimate with 95% confidence interval if reported, and certainty assessment. To minimize double interpretation arising from overlapping primary clinical trials among meta-analyses, overlap was considered during synthesis by (1) identifying reviews that addressed similar intervention–outcome pairs and (2) prioritizing the most comprehensive and methodologically robust reviews when multiple reviews synthesized substantially overlapping evidence.

Methodological quality appraisal of included reviews (AMSTAR-2)

The methodological quality of included systematic reviews was appraised using AMSTAR-2. The methodological quality of the included systematic reviews was evaluated using AMSTAR-2. Each review was evaluated based on the AMSTAR-2 domains and categorized according to the overall level of confidence (high, moderate, low, or very low). This review level assessment was used to contextualize interpretations across intervention domains, particularly when effect estimates were consistent but supported by reviews with different levels of methodological certainty.

Certainty of evidence (GRADE)

Certainty of evidence was summarized using the GRADE approach as reported in the included meta-analytic reviews. No independent re-grading of primary trials was undertaken, consistent with the methodological boundaries of an umbrella review. Reported certainty ratings (high, moderate, low, very low) were compared across outcomes and intervention domains to support interpretation of the robustness and consistency of the evidence.

RESULTS

Study selection

The study selection process is presented in Figure 1. A total of 121 records were identified from PubMed, Scopus, Web of Science, and SPORTDiscus. After title and abstract screening, 45 full-text articles were assessed for eligibility, and 30 were excluded due to a non-eligible population (e.g., older age groups), single-component interventions outside the predefined multicomponent scope, inappropriate outcomes, non-eligible publication types (e.g., protocols), or incomplete reporting. Fifteen meta-analytic reviews met the eligibility criteria and were included in the umbrella review (Figure 1).

Characteristics of included meta-analytic reviews

The included evidence comprised systematic reviews with meta-analysis and network meta-analyses evaluating non-pharmacological rehabilitation approaches for osteoarthritis, predominantly KOA (Table 1). The reviews varied in scope and evidence base, ranging from smaller meta-analyses to large-scale evidence syntheses.^{7,11,17} Populations and settings were heterogeneous, including knee-only KOA and mixed hip/knee osteoarthritis populations (Table 1). Age- and BMI-stratified subgroup analyses were not consistently reported; therefore, most pooled estimates reflect mixed KOA populations with indirect relevance to overweight young adults with early-stage or early-onset KOA. One included review examined sports participation as an osteoarthritis risk factor and was treated as etiological context rather than an intervention-effectiveness domain.¹⁸

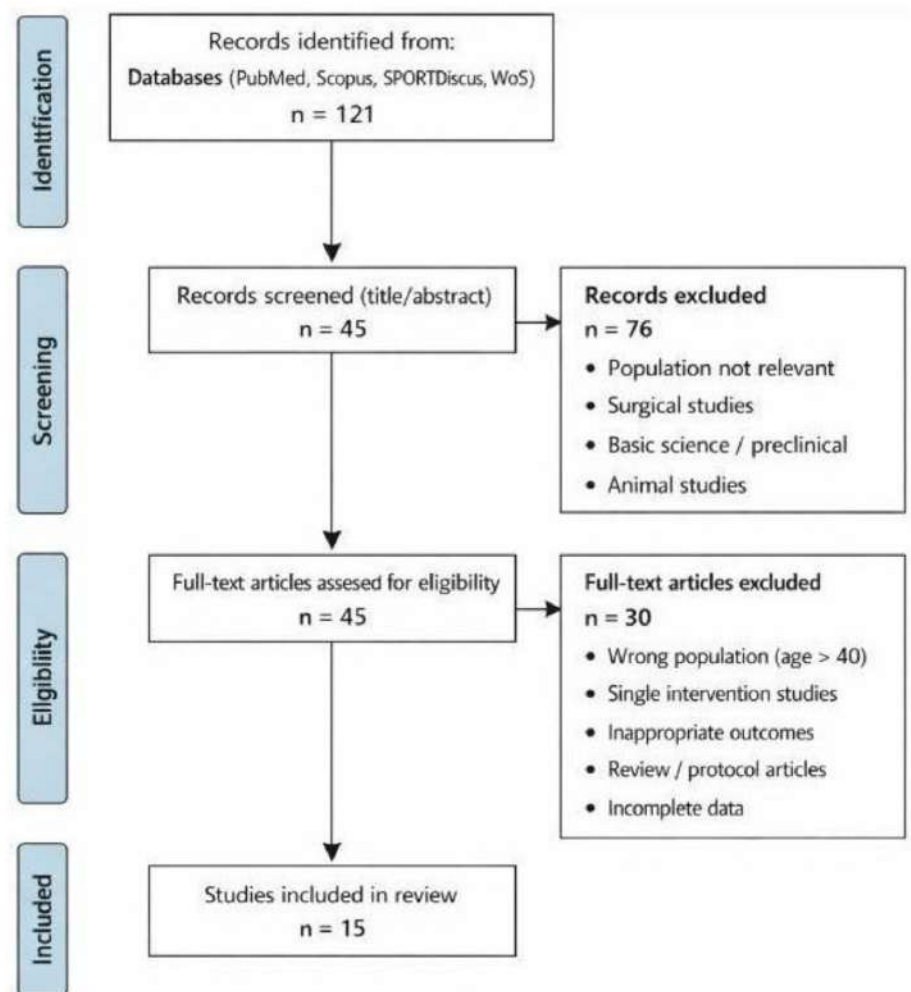


Figure 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram illustrating the study selection process

Terminology and domain framework used for synthesis

For consistency, this umbrella review used Sport-Medicine-Oriented Holistic Rehabilitation (SMOHR) as an organizational framework for multicomponent conservative care. Here, multicomponent rehabilitation refers to programs that include exercise-based therapy plus at least one additional domain (e.g., education/self-management, psychosocial support, lifestyle/weight-related strategies). Multidisciplinary rehabilitation is treated as a delivery model that may align with SMOHR when multiple domains are implemented within a coordinated program.^{6,14,19}

Effects of rehabilitation interventions by domain

Exercise-based and activity-focused rehabilitation (core biomechanical domain)

Across reviews, exercise-based rehabilitation was consistently associated with improvements in pain and physical function outcomes.^{7,12} In the Cochrane review, exercise was associated with short-term improvements across three comparator categories. Exercise vs attention control/placebo: pain improved by 8.70 points (0–100 scale; 95% CI 5.70 to 11.70), and physical function improved by 11.27 points (95% CI 7.64 to 15.09), while quality of life showed little to no change (6.06 points; 95% CI –0.13 to 12.26). Exercise vs no treatment/usual care/limited education: pain improved by 13.14 points (95% CI 10.36 to 15.91), physical function improved by 12.53 points (95% CI 9.74 to 15.31), and quality of life improved slightly (5.37 points; 95% CI 3.19 to 7.54). Exercise added to another co-intervention vs co-intervention alone:

Table 1. The characteristics of 15 included studies

Author (year)	Country	Study design	Sample size	Intervention	Outcome measures / Instruments	Key findings
AL-Mhanna et al. (2022) ¹³	Malaysia, Saudi Arabia, Nigeria	Systematic Review and Meta-Analysis	Pooled data from multiple controlled trials	Circuit training programs for knee OA	Pain scales, physical function, QoL; pooled SMD with 95% CI	Circuit training significantly reduced pain compared with control (SMD -0.96), while effects on physical function, QoL, stiffness, and activities of daily living were not statistically significant.
Chen et al. (2025) ¹¹	China	Network meta-analysis	9,644 patients (139 RCTs)	Non-pharmacological interventions	WOMAC, VAS-activity	Knee brace most effective across outcomes; hydrotherapy second; ultrasound least effective
Girish & Subhadra (2025) ¹	International	Systematic review & meta-analysis	Multiple RCTs	Exercise-based rehabilitation	WOMAC, pain scales, QoL	All exercise types improved KOA outcomes; aquatic exercise best for pain, yoga best for stiffness and QoL
Hua et al. (2023) ²¹	Amerika Serikat / Internasional (review)	Systematic Review & Meta-Analysis of RCTs	Dozens of RCTs (thousands of participants)	Structured physical exercise interventions for knee osteoarthritis	WOMAC, VAS, Quality of Life measures	Physical exercise significantly improved pain, physical function, and quality of life in knee osteoarthritis patients
Tzu-Han et al. (2025) ¹⁴	Taiwan	Meta-analysis	7 RCTs	Multidisciplinary rehabilitation care	Kinesiophobia scales	Multidisciplinary care reduced kinesiophobia with effects lasting up to 6 months
Johnson et al. (2022) ¹⁷	United States	Systematic Review & Meta-Analysis	381 RCTs	Rehabilitation and non-pharmacological pain management interventions	WOMAC, VAS, Quality of Life measures	Rehabilitation interventions demonstrated moderate to large effects in reducing pain and improving functional outcomes
Runge et al. (2022) ¹⁶	International	Systematic Review with Meta-Analysis	Multiple RCTs involving knee and hip OA patients	Manual therapy combined with exercise vs exercise alone	WOMAC (pain, function, stiffness), performance-based outcomes	Meta-analysis showed very low to moderate certainty evidence of short-term pain and WOMAC global score improvement with added manual therapy, but high-certainty evidence of no long-term benefit for pain and function.
Minea et al. (2025) ²³	Romania	Systematic review & meta-analysis	7 studies	Rehabilitation strategies	Gait speed, QoL scales, pain measures	Significant improvement in gait speed, QoL, pain reduction, and fall risk
Mo et al. (2023) ¹²	Internasional (multi-negara, systematic review & meta-analysis)	Systematic Review & Network Meta-Analysis	>100 RCTs	Non-pharmacological interventions (exercise, knee brace, hydrotherapy, physical modalities)	WOMAC, VAS during activity	Knee braces and hydrotherapy showed superior effectiveness compared with conventional exercise programs
Sasaki et al. (2022) ¹⁹	Japan (international studies)	Systematic Review with Meta-Analysis	Multiple RCTs (number varied across outcomes)	Exercise and/or educational interventions for hip/knee OA	Physical activity measures, pain scales; pooled using SMD and 95% CI	Meta-analysis showed low to very low certainty evidence that combined exercise and education modestly improved physical activity (SMD 0.33) and reduced pain (SMD -0.15) compared with controls.

Table 1. Lanjutan

Author (year)	Country	Study design	Sample size	Intervention	Outcome measures / Instruments	Key findings
Tayfur et al. (2023) ²²	Turkey	Systematic Review & Meta-Analysis	Multiple RCTs (varied sample sizes)	Therapeutic exercise programs for knee osteoarthritis	WOMAC, VAS, physical function scores	Therapeutic exercise significantly reduced pain and improved physical function in patients with knee osteoarthritis
Goff et al. (2021) ⁶	Australia	Systematic review of randomized controlled trials	4,107 participants (29 trials)	Patient education as a standalone intervention or combined with exercise therapy, compared with usual care or other non-pharmacological comparators	Self-reported pain and function (including WOMAC-based comparisons)	Patient education alone showed only small short-term benefits versus usual care and was inferior to exercise alone for pain; education combined with exercise produced better short-term pain and function outcomes than education alone.
Whittaker et al. (2022) ²⁴	United Kingdom	Systematic Review & Meta-Analysis	Multinational RCTs	Activity-based and exercise-focused rehabilitation	WOMAC, pain intensity, physical function	Active rehabilitation interventions provided clinically meaningful improvements in pain and disability
Bestwick-Stevenson et al. (2021) ¹⁸	United Kingdom (international data)	Systematic Review and Meta-Analysis	Observational cohort and case-control studies	Sports participation exposure (risk factor analysis; non-therapeutic)	Relative Risk (RR) with 95% CI, pooled estimates	Meta-analysis demonstrated Certain high-impact sports were associated with increased OA risk (etiological context, not treatment effect) associated with certain sports (e.g., wrestling and ice hockey), with pooled RR indicating significantly higher OA incidence compared with non-athletes.
Cochrane Central Editorial Service et al. (2024) ⁷	Australia / International	Cochrane systematic review and meta-analysis of RCTs	12,468 participants (139 RCTs)	Exercise for knee OA compared with attention control/ placebo, usual care/ no treatment/limited education, or exercise added to another co-intervention	Pain severity, self-reported physical function, quality of life, treatment success, adverse events, withdrawals	Exercise probably improved pain, physical function, and quality of life in the short term, but the magnitude of benefit was of uncertain clinical importance; no clear differences were found between exercise types.

pain improved by 10.43 points (95% CI 8.06 to 12.79), physical function improved by 9.66 points (95% CI 7.48 to 11.97), and quality of life improved by 4.22 points (95% CI 1.36 to 7.07).

The same Cochrane review noted that, when compared with pre-specified minimal important difference thresholds, the clinical importance of these effects was uncertain for some outcomes because confidence intervals did not reach or could include values below those thresholds.⁷

In a circuit-training-focused meta-analysis, pain reduction was reported (SMD -0.96), while pooled effects for

physical function and quality of life were not consistently statistically significant within that review's synthesis.¹³ A network meta-analysis comparing exercise modalities reported WOMAC improvements versus control conditions for most exercise categories and presented comparative ranking probabilities (SUCRA) for outcome-specific performance.¹² Additional syntheses of strength training and therapeutic exercise also reported improvements in pain and function outcomes in KOA populations.²⁰⁻²²

Aquatic therapy/hydrotherapy and knee bracing (supportive modalities within conservative care)

Network meta-analyses comparing multiple conservative interventions reported that knee bracing and hydrotherapy/aquatic therapy showed favorable comparative ranking probabilities across WOMAC-related outcomes, with rankings summarized using SUCRA. In that review, knee bracing was reported as having lower WOMAC pain scores than lateral wedged insoles in specified contrasts, and hydrotherapy showed favorable comparisons on

Table 2. A measurement tool to assess systematic reviews version 2 (AMSTAR-2) overall confidence.

Included review	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15	I16	Overall confidence	Notes (brief)
AL-Mhanna et al. (2022) ¹³	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Partial Yes	No	Yes	No	Yes	Yes	No	Yes	Critically low	Protocol/registration not clearly reported; excluded full-text list not provided; publication bias assessment unclear.
Chen et al. (2025) ¹¹	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Moderate	Strong reporting; funding of included primary studies was not reported.
Girish & Subhadra (2025) ¹	No	No	No	No	No	No	No	No	No	No	Not applicable	Not applicable	No	No	Not applicable	No	Critically low	Reporting does not fully match systematic review standards required for AMSTAR-2 appraisal.
Hua et al. (2023) ²¹	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Low	Protocol and excluded studies list not clearly reported; publication bias assessment unclear.
Tzu-Han et al. (2025) ¹⁴	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Low	The protocol and excluded studies lists are not clearly verifiable.
Johnson et al. (2022) ¹⁷	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Low	The list of excluded studies was not clearly reported in accessible materials.
Runge et al. (2022) ¹⁶	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Low	Protocol/registration and publication bias investigation unclear.
Minea et al. (2025) ²³	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Low	Protocol/registration and excluded studies list not clearly reported; publication bias unclear.
Mo et al. (2023) ¹²	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Low	Strong methods; excluded full-text list not explicitly reported.
Sasaki et al. (2022) ¹⁹	Yes	No	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Low	Protocol/registration and publication bias investigation not clearly reported.
Tayfur et al. (2023) ²²	Yes	Yes	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Low	Some reporting elements (excluded studies list; publication bias) unclear.
Goff et al. (2021) ⁶	Yes	Yes	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes	Yes	No	Yes	Low	Excluded studies list and publication bias reporting not clearly presented.
Whittaker et al. (2022) ²⁴	No	No	No	Partial Yes	No	No	No	Partial Yes	Not applicable	No	Not applicable	Not applicable	No	No	Not applicable	Yes	Critically low	“Year-in-review” style synthesis; not a conventional SR/MA with full AMSTAR-2 reporting.
Bestwick-Stevenson et al. (2021) ¹⁸	Yes	Yes	Yes	Partial Yes	Yes	Yes	No	Yes	Yes	No	Partial Yes	No	Yes	Yes	No	Yes	Low	Exposure/risk-factor review; interpret cautiously because not intervention effectiveness.
Cochrane Central Editorial Service et al. (2024) ⁷	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High	Cochrane methods; comprehensive search, RoB, publication bias, and COI reporting.

Table 3. Summary of evidence certainty using grading of recommendations assessment, development, and evaluation (GRADE) for non-pharmacological rehabilitation interventions in osteoarthritis

Author (year)	Type of intervention	Primary outcomes	Certainty of evidence using GRADE	Basis for certainty assessment
AL-Mhanna et al. (2022) ¹³	Circuit training	Pain, physical function	Moderate	Meta-analysis of RCTs demonstrating large effect sizes with moderate heterogeneity
Chen et al. (2025) ¹¹	Non-pharmacological interventions (network meta-analysis)	Pain, function (WOMAC, VAS)	Moderate–High	Large number of RCTs (n = 139) with consistent findings across key interventions
Girish & Subhadra (2025) ¹	Exercise-based rehabilitation	Pain, physical function, quality of life	Moderate	Multiple RCTs; variability in exercise types and intervention intensity
Hua et al. (2023) ²¹	Structured physical exercise	Pain, physical function, quality of life	High	Predominantly high-quality RCTs with consistent effects and high precision
Tzu-Han et al. (2025) ¹⁴	Multidisciplinary rehabilitation care	Kinesiophobia	Low–Moderate	Limited number of RCTs and relatively small sample sizes
Johnson et al. (2022) ¹⁷	Rehabilitation and non-pharmacological pain management	Pain, physical function	Moderate–High	Large-scale meta-analysis (381 RCTs) with heterogeneity due to intervention diversity
Runge et al. (2022) ¹⁶	Manual therapy combined with exercise	Pain, physical function	Low–Moderate	Short-term benefits observed; limited evidence of long-term effectiveness
Minea et al. (2025) ²³	Rehabilitation strategies	Gait speed, quality of life	Moderate	Small number of included studies with clinically consistent outcomes
Mo et al. (2023) ¹²	Non-pharmacological interventions (network meta-analysis)	Activity-related pain, physical function	Moderate–High	Multi-intervention comparisons with controlled heterogeneity
Sasaki et al. (2022) ¹⁹	Exercise combined with education	Physical activity, pain	Low	Risk of bias and imprecision reduced overall certainty
Tayfur et al. (2023) ²²	Therapeutic exercise	Pain, physical function	Moderate	Consistent effects across studies with variability in exercise protocols
Whittaker et al. (2022) ²⁴	Activity-based rehabilitation	Pain, disability	Moderate	Clinically meaningful effects with heterogeneity in rehabilitation approaches

function and/or total WOMAC outcomes in certain contrasts. The review also reported that hydrotherapy, exercise, and several physical modalities frequently clustered among comparatively favorable options depending on the endpoint assessed, while acknowledging that not all pairwise comparisons reached statistical significance.¹¹ A separate network meta-analysis focusing on exercise-based therapies similarly reported WOMAC-related improvements versus controls and presented SUCRA-based rankings across outcomes.¹² These findings were synthesized as comparative evidence primarily derived from mixed KOA populations rather than subgroup-specific estimates for overweight young adults.

Manual therapy combined with exercise (adjunctive domain)

Evidence comparing manual therapy plus exercise versus exercise alone suggested time-dependent patterns. One systematic

review with meta-analysis reported very low-to-moderate certainty evidence of short-term additional benefit for pain and WOMAC global scores, low-to-very low certainty evidence for some medium-term outcomes, and high-certainty evidence indicating no added long-term benefit for pain and function.¹⁶ This evidence was treated as adjunctive support relevant to combined conservative programs rather than as stand-alone multicomponent rehabilitation.

Education/self-management and psychosocial outcomes (behavioral domain)

Evidence addressing education and psychosocial components was synthesized from reviews that specifically evaluated these domains. A systematic review reported that patient education alone produced small short-term benefits versus usual care and was inferior to exercise alone for pain in the short term; education

combined with exercise was associated with better outcomes than education alone for short-term pain and function, and for function at medium-term follow-up in some comparisons.⁶ Another systematic review with meta-analysis reported modest pooled effects for exercise and/or educational interventions, including an improvement in physical activity (SMD 0.33) and a small reduction in pain (SMD -0.15) compared with controls, with certainty described as low to very low.¹⁹ A meta-analysis of multidisciplinary complementary interventions in a postoperative context reported reductions in kinesiophobia, with an overall pooled effect size of SMD -0.82 (95% CI -1.08 to -0.56); heterogeneity varied by time point.¹⁴ Because that review focused on postoperative rehabilitation, its findings were interpreted as behavioral/psychosocial evidence with limited direct applicability to early-stage KOA.

Gait and broader functional outcomes (performance domain)

A systematic review and meta-analysis focusing on gait speed reported improvement following rehabilitation-related interventions, with a pooled effect size of SMD 1.807 (95% CI 1.637 to 1.977; $p < 0.001$) and substantial heterogeneity attributed to variation in intervention types and study populations.²³ This evidence was interpreted as performance-oriented support for rehabilitation effects in KOA, with caution regarding heterogeneity.

Etiological context (not an intervention-effectiveness domain)

One included meta-analysis evaluated sports participation as an exposure associated with osteoarthritis risk rather than intervention effectiveness; it was retained for contextual framing and was not synthesized as a rehabilitation-effectiveness domain.¹⁸

Methodological quality (AMSTAR-2) and certainty of evidence (as reported)

Methodological quality assessed using AMSTAR-2 ranged from high and moderate to low/critically low in several reviews (Table 2).^{1,7,11,13,24} This review-level appraisal was used to contextualize interpretation across domains, particularly when findings were derived from syntheses with limited reporting completeness.

Certainty of evidence using GRADE was not consistently reported across included reviews. Where certainty statements were explicitly available, they were summarized without re-grading. For example, the Cochrane review reported low-to-moderate certainty evidence depending on the comparator and outcome for exercise effects.⁷ Low-to-very low certainty was reported for combined exercise and education effects in one review, and certainty statements varying by time horizon were reported for manual therapy added to exercise.^{16,19} For several other included reviews, explicit GRADE ratings were not available in the information provided and were therefore recorded as “not reported” (Table 3).

DISCUSSION

This umbrella review synthesized meta-analytic evidence published between

2021 and 2025 on non-pharmacological, multicomponent rehabilitation approaches for knee osteoarthritis (KOA), with emphasis on potential applicability to overweight young adults with early-stage or early-onset presentations. Across the included reviews, conservative modalities—particularly exercise-based interventions, aquatic therapy/hydrotherapy, and knee bracing—were associated with improvements in pain and physical function, and several syntheses also reported benefits in quality of life or selected functional indicators.^{7,11,12,23} However, the strength and certainty of evidence varied across intervention domains and outcomes, and the included reviews frequently pooled heterogeneous KOA populations, which limits direct inference for overweight young adults specifically.^{7,12}

The convergence of findings across multiple review-level syntheses supports exercise-based rehabilitation as a core component within conservative KOA management.^{7,12} This aligns with contemporary views that exercise targets neuromuscular function, strength, and movement capacity—constructs that are clinically relevant to pain-related disability and functional limitations in KOA.^{7,12} In parallel, aquatic therapy/hydrotherapy has been evaluated as a lower-load exercise environment and has been reported as beneficial for pain and functional outcomes within multimodal comparisons.^{11,12} Knee bracing has also been associated with improvements in WOMAC-based outcomes in network meta-analytic comparisons, suggesting that supportive modalities may complement active rehabilitation in symptom and function management.¹¹

Evidence addressing adjunctive manual therapy within combined programs was mixed. In one systematic review and meta-analysis, adding manual therapy to exercise was associated with short-term improvements in pain and WOMAC global scores, whereas long-term benefits for pain and function were not supported, with the review reporting high-certainty evidence of no additional long-term effect.¹⁶ Taken together, these findings support a conservative approach in which multicomponent packages are organized

around complementary elements, while recognizing that incremental benefit from adjunctive components may differ by outcome domain and follow-up window.^{25,26}

Psychosocial outcomes, particularly kinesiophobia, emerged as clinically relevant targets in selected meta-analytic reviews.^{15,22} Educational and self-management components may be important for addressing barriers to adherence and sustained activity engagement, which are commonly emphasized in rehabilitation frameworks and osteoarthritis physical activity recommendations.^{27–29} A systematic review focusing on patient education reported that education alone produced small short-term improvements versus usual care and that education combined with exercise yielded better short-term pain and function outcomes than education alone.²⁴ Similarly, exercise and/or education programs have been associated with modest improvements in physical activity and small reductions in pain, although certainty was reported as low to very low in the corresponding review.⁸ In a separate meta-analysis, multidisciplinary complementary interventions were associated with reductions in kinesiophobia across several postoperative time points, although heterogeneity was substantial in some subgroup analyses.³⁰ Collectively, these findings indicate that psychosocial and behavioral domains may contribute to rehabilitation outcomes; however, effects and certainty may vary across program content, delivery context, and outcome selection.^{31–34}

Although this umbrella review was motivated by increasing recognition of KOA in overweight young adults, the included meta-analyses commonly synthesized broad KOA populations across age ranges and disease stages, and age- or BMI-stratified subgroup estimates were rarely reported.^{35–37} Consequently, many pooled estimates should be interpreted as indirect evidence for overweight young adults with early-stage or early-onset KOA. This limitation is important because obesity-related KOA involves both mechanical loading and systemic metabolic-inflammatory pathways that

may influence symptom burden and response to rehabilitation.^{3,38,39} Therefore, future evidence synthesis and primary trials would benefit from clearer subgroup reporting and standardized definitions for early-stage/early-onset KOA.

In addition, definitions of “early-onset” and “early-stage” KOA were not consistently operationalized across reviews. For this umbrella review, these terms were interpreted pragmatically as younger-age and/or earlier-stage KOA as defined by included evidence sources, rather than a single standardized threshold. This supports synthesis while highlighting the need for consistent staging and age reporting in future studies.⁴⁰

To translate the included evidence into a clinically interpretable structure, Sport-Medicine-Oriented Holistic Rehabilitation (SMOHR) is used here as an organizing framework rather than a distinct intervention modality. SMOHR groups relevant components into biomechanical optimization through exercise-based rehabilitation and supportive modalities (eg, bracing), metabolic and lifestyle strategies relevant to overweight populations, psychosocial support to address pain-related behaviors and adherence barriers, and continuity of care through follow-up and self-management support.^{7,11} Within the included meta-analytic literature, the most consistently supported domains were biomechanical/functional components (exercise, aquatic therapy, bracing), whereas self-management outcomes were supported with more variable certainty.^{6,7,11,19} Evidence specifically isolating weight-management or metabolic regulation components within multicomponent packages was limited in the included meta-analyses, even though mechanistic literature highlights their relevance in obesity-related KOA.²⁻⁴

Several limitations should be noted. First, umbrella reviews can be influenced by overlap of primary trials across meta-analyses, potentially amplifying repeatedly synthesized evidence. Second, intervention protocols, comparators, and outcome measures varied substantially across reviews, which may contribute to inconsistency and reduce comparability of pooled estimates.^{6,25,37} Third, behavioral

and exercise-based interventions commonly face constraints in blinding, which can increase the risk of bias in the primary literature and affect the interpretation of effect estimates.^{13,20,39} Finally, certainty of evidence was summarized based on what was reported in the included reviews, and re-grading of primary trials was not conducted, consistent with the methodological boundaries of umbrella reviews.

Future research should prioritize evidence that improves applicability to overweight young adults with early-stage or early-onset KOA. Key priorities include: consistent operational definitions for early-stage/early-onset KOA, explicit reporting of age- and BMI-stratified effects, longer-term follow-up evaluating adherence and sustained function, and transparent reporting and testing of clearly defined multicomponent packages that integrate exercise with psychosocial and weight-related lifestyle components.^{2,22,30}

CONCLUSION

Meta-analytic evidence published between 2021 and 2025 suggests that conservative, non-pharmacological rehabilitation, particularly exercise-based interventions, hydrotherapy, and knee bracing is associated with improvements in pain and physical function in knee osteoarthritis. Evidence for multicomponent approaches that incorporate education/self-management and psychosocial support appears more inconsistent across outcomes; however, several reviews indicate potential benefits for outcomes linked to adherence and fear of movement. Because most included reviews synthesized heterogeneous KOA populations and rarely reported age- or BMI-stratified subgroup effects, the applicability of pooled estimates to overweight young adults with early-stage or early-onset KOA remains limited. Within these constraints, SMOHR, as operationalized in this umbrella review, can be used as an organizing framework to map intervention domains and to guide priorities for future trials and meta-analyses that explicitly target younger and overweight populations.

ETHICS STATEMENT

Ethical approval was not required for this study because it is a secondary research study (systematic review of published systematic reviews and meta-analyses) and did not involve direct recruitment of human participants, collection of identifiable private data, or any intervention.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

Conceptualization, methodology, supervision MY; writing—review & editing MY, S, MA, ESW; literature search, screening, data curation and extraction S and GEV; quality assessment, data synthesis/meta-analysis support, writing—original draft, visualization GEV; methodology, statistical/analytical guidance, interpretation MA; clinical expertise (knee osteoarthritis/rehabilitation perspective), interpretation ESW.

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