

The Role of Flexibility in Predicting Health and Disease Progression in Patients with Chronic Health Conditions: A Systematic Review and Meta-Analysis

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Abstract

Background

Flexibility is widely recognised as a core component of health-related physical fitness, yet its value as an independent predictor of future health outcomes remains uncertain.

Objective

To systematically review and meta-analyse prospective cohort studies examining associations between flexibility and future health outcomes in adults with chronic conditions, emphasising clinically meaningful applications and identifying research gaps.

Methods

We systematic searched MEDLINE, Embase, Emcare, CINAHL Complete, and SPORTDiscus (January 2005–April 2025). Eligible studies were prospective cohorts assessing objectively measured flexibility or joint range of motion (ROM) against subsequent health or disease-specific outcomes in adults (≥ 18 years) with diagnosed chronic conditions. Risk of Bias was assessed using the CLARITY Group tool, and certainty of evidence was evaluated using GRADE, focussing on clinical relevance.

Results

Thirty-five studies ($n=19\,239$; 53% female, mean age 55.7 ± 14.5 years, median follow-up 2.0 years [range 0.25 to 15 years]) across 14 conditions were included. Substantial heterogeneity precluded pooling of results. A single meta-analysis in patients with hip and/or knee osteoarthritis (OA) provided moderate certainty of evidence of no association between flexibility and pain, stiffness, or physical function ($r=0.14$; 95%CI: $-0.03-0.29$, $p = 0.09$). Narrative synthesis indicated that reduced knee extension ROM predicted radiological disease progression and total knee replacement in knee OA, while the Bath Ankylosing Spondylitis Metrology Index (BASMI) reliably tracked disease progression in axial spondyloarthritis. No longitudinal evidence was identified for major chronic conditions such as cardiovascular disease, diabetes, cancer, chronic respiratory diseases, obesity, or osteoporosis, highlighting critical research gaps.

Conclusion

Current evidence offers limited support for flexibility as a prognostic marker in chronic conditions. Condition-specific, multi-joint assessments (e.g., BASMI or joint-specific ROM) may provide greater clinical utility, but high-quality longitudinal studies are urgently needed to determine whether flexibility can meaningfully guide prognosis and inform clinical decision making.

Trial Registration PROSPERO CRD420251029178.

Key Points

- Flexibility is a key health-related component of physical fitness, but its value as a predictor of future health remains unclear. This is the first study to systematically evaluate baseline flexibility associated with future health outcomes in adults with chronic conditions.
- Thirty-five longitudinal studies (> 19 000 patients; 14 conditions) were identified. Due to heterogeneity, only one meta-analysis was feasible, showing no association between range of motion and pain, stiffness, or function in patients with osteoarthritis; all other results were synthesised narratively.
- Evidence suggests potential associations between knee extension range of motion (ROM) and both radiological disease progression and total knee replacement in patients with osteoarthritis, and supports the Bath Ankylosing Spondylitis Metrology Index (BASMI) as a tool for monitoring disease progression in patients with axial spondyloarthritis.
- Higher-quality longitudinal studies are needed to clarify the prognostic role of flexibility in chronic disease.

1. Introduction

Physical fitness reflects measurable attributes that enable individuals to perform daily tasks effectively, sustain or improve health, and reduce chronic disease risk [1]. These attributes are typically categorised as skill-related (e.g., muscular power, speed, agility) or health-related (e.g., cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, and body composition) [1–3]. Extensive evidence consistently demonstrates that higher cardiorespiratory endurance and muscular strength are strongly associated with reduced risk of all-cause mortality [4–7], cardiovascular disease [4–8], and cancer [5–10]. In contrast, few cohort studies have examined the prospective association between flexibility and health outcomes.

Flexibility—the ability to move a joint or body segment through its full range of motion without pain or discomfort—is widely assessed in practice [11–13]. Flexibility is used in schools to evaluate general fitness [14], in rehabilitation to monitor recovery from injury [15], and in older adults to evaluate fall risk [16]. When deficits are identified, stretching is commonly prescribed based on the assumption that stretching will improve flexibility and, therefore, enhance physical performance or reduce risk [17–19]. However, this assumption rests on limited prospective evidence linking flexibility to future health outcomes, raising legitimate questions about its status as a core health-related fitness component [20].

To date, only a single systematic review has examined flexibility in relation to health outcomes, identifying just three studies [21–23] and reporting limited evidence for associations with falls, mobility, disability, and all-cause mortality [24]. Given the longstanding inclusion of flexibility in health-related fitness frameworks, this narrow evidence base is insufficient.

In addition, while the relationship between flexibility and health is unclear in the generally healthy adult populations, even less is known in individuals diagnosed with chronic conditions, where its clinical relevance may be greatest. Therefore, this study aimed to systematically review, and where possible meta-analyse, the prospective association between flexibility and health outcomes in adults diagnosed with chronic health conditions.

2. Methods

2.1. Protocol and registration

This systematic review and meta-analysis was prospectively registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD420251029178) on 9 April 2025 and followed the 2020 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement [25].

An initial comprehensive review examining associations between flexibility and health outcomes in adults (≥ 18 years) was subsequently divided into two population-specific reviews. This review included studies of adults with diagnosed chronic health conditions at baseline. A companion systematic review in apparently healthy adults is reported elsewhere.

2.2. Eligibility criteria

The PECOS (Population, Exposure, Outcome, and Study design) framework guided our inclusion criteria:

Population: Adults (≥ 18 years) with a diagnosed chronic health condition at baseline. Studies involving special interest groups (i.e., elite athletes, military studies, post-surgical cohorts, acute injury and illness, congenital diseases, and pregnant individuals) were excluded.

Exposure: Any objective measure of flexibility or joint range of motion at any specific muscle, joint, or region of the body (i.e., sit-and-reach test, goniometric ROM in angular degrees or distance).

Outcome(s): Any health condition or outcome assessed using objective measures (e.g., mortality, biomarkers, incident disease), observed measures (e.g., clinical diagnosis), or self-reported measures (e.g., patient-reported outcome measures) criteria.

Study design: Prospective cohort studies examining the association between baseline flexibility (or ROM) and future outcomes, including disease progression (i.e., radiological progression of osteoarthritis [OA]), physical performance (i.e., gait, activities of daily living [ADLs], Timed Up and Go [TUG], sit-to-stand, balance), or quality of life (i.e., 36-Item Short Form Survey). For inclusion, studies were required to report effect estimates (odds ratios, relative risks, hazard ratios) or continuous outcomes (e.g., beta-coefficients, mean differences, standardised effect sizes).

Language, publication status and timeframe: Peer-reviewed, full-text articles in English from 1 January 2005 onwards [26, 27]. Scoping searches conducted with experienced academic librarians indicated

that including earlier literature substantially increased retrieval volume without proportionate gains in methodological quality or relevance, thereby compromising feasibility. Therefore, limiting the timeframe balanced comprehensiveness with practicality while maintaining the recency and applicability of evidence. Conference abstracts, commentaries, editorials, and dissertations were excluded.

2.3. Information sources and search strategy

A search strategy for online databases was developed in collaboration with two academic librarians who specialize in systematic reviews. The following databases were searched on 9 April 2025; MEDLINE (Ovid), Embase (Ovid), Emcare (Ovid), CINAHL Complete (EBSCOhost), and SPORTDiscus (EBSCOhost). The specific search strategies employed for each database can be found in Supplementary File 1. Additionally, reference lists from included studies and relevant topical systematic reviews and meta-analyses, were screened for additional studies not captured by the primary systematic search to ensure comprehensive coverage.

2.4. Selection process

Records were imported into EndNote (v20.2.1; Clarivate Analytics, Philadelphia, PA, USA) and initial de-duplicated before being exported into Covidence (Veritas Health Innovation, Melbourne, VIC, Australia) for secondary de-duplication and record screening. All titles and abstracts were independently screened against inclusion criteria by two of the following authors (LI, HB, JL, ND, BG, EO and GT). Full-text studies were independently screened by two authors (LI and HB) against inclusion criteria with conflicts resolved by negotiation.

2.5. Data collection process and data items

A single author (LI) extracted data from all included full-text studies using a custom-made standardised Excel spreadsheet (Microsoft, Redmond, WA, USA), which was independently verified for accuracy by a second author (BG). The following data were extracted from each included study:

- a. First author surname and year of publication;
- b. Article title;
- c. Trial name (if applicable);
- d. Country in which the study was conducted;
- e. Descriptive characteristics, including sample size, sex, age, height, body mass, body mass index [BMI], clinical condition, disease progression;
- f. Objective measure(s) of flexibility or joint range of motion reported;
- g. Duration of follow-up;
- h. Primary health-related outcome(s) and/or measure(s) of disease progression, including effect estimates (i.e., odds ratios, relative risks, hazard ratios, or beta-coefficients) and measures of variability (e.g., 95% confidence intervals); and

i. Covariates included in adjusted analyses.

Visually presented results were approximated using WebPlotDigitizer (v4.6; Ankit Rohatgi, Melrose, MA, USA [<http://apps.automeris.io/wpd/>]) [28].

2.6. Risk of bias assessment

Three authors (LI, BG, and ND) independently assessed study quality using The Tool to Assess Risk of Bias in Cohort Studies (CLARITY Group at McMaster University) with conflicts resolved by negotiation between authors. The Tool to Assess Risk of Bias in Cohort Studies is an 8-item checklist that quantifies potential sources of bias. The tool assesses whether exposed and non-exposed participants were selected from the same population; the validity and robustness of the exposure assessment; the extent of matching and statistical adjustment for variables associated with the outcome of interest; the validity of outcome assessment; the adequacy of follow-up; and the degree to which co-interventions were similar between groups [29]. Each item was rated as “definitely yes” = 3, “probably yes” = 2, “probably no” = 1, or “definitely no” = 0. Higher scores indicated higher methodological quality and, therefore, a lower risk of bias.

2.7. Certainty of evidence

Two authors (LI and HB) independently assessed the certainty of evidence using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) framework for each specific chronic disease group [30]. Each outcome within each specific disease group was assessed separately and rated as high, moderate, low, or very low certainty of evidence. Certainty of evidence was initially rated as ‘high’ based on the inclusion of prospective cohort studies because randomised controlled trials were not considered feasible for the research question [31]. The certainty was subsequently downgraded in the presence of: (a) serious risk of bias (defined as >20% of participants from studies of poor or moderate methodological quality) [32], (b) inconsistency of results ($I^2 > 50\%$, indicating substantial heterogeneity) [33], (c) indirectness of evidence (e.g., important differences in populations or outcomes assessed) [34], (d) imprecision (<4000 participants per outcome) [35], or (e) publication bias (evidence of small study effects based on a significant Egger’s test result) [36]. Alternatively, the certainty of evidence was upgraded if there was a large magnitude of effect, if all plausible residual confounding would attenuate the observed association, or demonstration of a dose-response gradient.

2.8. Deviations from registered protocol

Initially there were no restrictions placed on study design due to an anticipated lack of prospective cohort studies. However, the review was subsequently restricted to prospective cohort designs given the large number of eligible studies identified. Inclusion of other observational study designs would have rendered the study unfeasible given the available resources.

The registered protocol specified the inclusion of both apparently healthy adults and individuals with clinically diagnosed chronic conditions. However, substantial differences in outcome measures between

these populations necessitated separate analyses. To ensure methodological consistency and comparability, the present study focuses on clinical populations. Findings for apparently healthy adults are reported in a separate, dedicated review.

2.9. Data Synthesis and Analysis

Quantitative synthesis of data was performed using the 'metafor' and 'clubSandwich' packages in R, with plots produced using the 'ggplot2' package (version 4.5.2; R Core Team, <https://www.r-project.org/>). A multi-level meta-analysis was conducted to examine the association between flexibility and health-related outcomes in clinical populations. Only outcomes where three independent cohorts contributed data that could be meta-analysed were synthesised quantitatively. This only occurred for a measure (Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC]) in a single population (OA), which all reported continuous outcomes. As such, continuous outcomes reported as linear associations, B coefficients (unstandardised regression coefficients), β coefficients (standardised regression coefficients), and correlation coefficients were converted to a common correlation metric. β coefficients were treated as correlation coefficients without conversion ($r = \beta$). B coefficients were converted to correlation coefficients using the approximation $r \approx B$ when $|B| < 1$. Correlation coefficients were retained without conversion. All correlation coefficients were transformed using Fisher's z transformation prior to meta-analysis: $z = 0.5 \times \ln[(1 + r) / (1 - r)]$. The variance of Fisher's z was calculated as $1/(n - 3)$, where n represents the sample size. When sample size was not directly reported but confidence intervals were available, n was estimated from the CI width using the formula: $n \approx 1/SE_z^2 + 3$, where $SE_z = (z_{upper} - z_{lower}) / (2 \times 1.96)$. Pooled Fisher's z estimates were back-transformed to the correlation scale for interpretation using the inverse transformation: $r = \tanh(z) = (e^{2z} - 1) / (e^{2z} + 1)$.

To account for dependency between multiple effect sizes from the same cohort, a three-level random-effects meta-analytic model was fitted using restricted maximum likelihood (REML) estimation. The model included random effects for both cohort (level 2) and individual comparisons within cohorts (level 3). This structure accounts for the nested dependency whereby multiple comparisons from the same cohort are more similar to each other than to comparisons from different cohorts. Different studies reporting results from the same cohort were assigned identical cohort identifiers to appropriately model the dependency structure. Cluster-robust variance estimation with small-sample corrections (CR2) was applied to generate robust standard errors, confidence intervals and p-values that account for potential model misspecification and the small number of cohorts [37]. For analyses of continuous outcomes, results are reported as pooled correlation coefficients (r) with 95% confidence intervals, back-transformed from Fisher's z. Statistical significance was set at $p < 0.05$.

Statistical heterogeneity between studies was assessed using τ^2 and I^2 statistics. The I^2 statistic represents the proportion of total variance attributable to between-study heterogeneity rather than sampling error, with values interpreted as negligible (0-40%), moderate (30-60%), substantial (50-90%) or considerable (75-100%) [38]. Publication bias and small-study effects were assessed visually using funnel plots and examined statistically using Egger's regression test, whereby the effect size was

regressed on its standard error within the multi-level model framework. A statistically significant association ($p < 0.05$) was interpreted as evidence of small-study effects, which may indicate publication bias. Influence analyses were conducted using a leave-one-cohort-out approach, whereby the meta-analysis was repeated iteratively with each cohort removed in turn. The percentage change in the pooled effect estimate when removing each cohort was calculated to identify potentially influential studies. When studies reported multiple comparisons from the same outcome (e.g., quartile-based analyses, or multiple B/β /correlation coefficients measuring similar constructs), all comparisons were included in the meta-analysis with dependency modelled through the nested random effects structure already described.

Each disease group was analysed separately. For disease groups that contained a sufficient number of studies, health outcomes were grouped by health dimension similarity: in patients with OA, (1) total knee arthroplasty (TKA); (2) incident radiographic OA and radiographic progression; (3) self-reported pain, stiffness, and physical function (WOMAC); and (4) objectively measured function (10-m timed walk test). In patients with axial spondyloarthritis, (1) structural and radiographic disease progression; (2) measures of disease activity; (3) functional limitations; (4) major adverse cardiovascular events (MACE); and (5) body mass index (BMI).

A single meta-analysis was conducted looking at the associations between flexibility and WOMAC scores – a validated self-reported measure of pain, stiffness, and physical function in patients with hip or knee OA. Results for all other outcome measures were synthesised narratively as fewer than three independent cohorts contributed data.

To visualise the distribution and direction of evidence across populations and outcomes, a bubble matrix was constructed. The bubble sizes reflect the number of independent study cohorts, rather than individual studies, to account for non-independence between shared participants. The direction of the evidence was determined using vote counting based on direction of effect, whereby the dominant direction was assigned when $\geq 70\%$ of findings within a cell were consistent[39]. This resulted in findings being classified as "positive" (greater flexibility associated with better outcomes), "No association," and "Mixed". All data and code are available on the Open Science Framework repository linked to this project (<https://osf.io/23s5y/files/osfstorage>).

3. Results

3.1. Study selection

The search yielded 78 673 records, of which 31 307 duplicates were removed. Following the screening of 47 366 titles and abstracts, 315 articles underwent full-text review, with 33 meeting inclusion criteria [23, 40–71]. Reference list screening identified another two articles [72, 73], resulting in 35 included studies. Figure 1 summarises the selection process. Inter-rater agreement ranged from a moderate to near perfect for title/abstract screening ($\kappa = 0.43$ and 0.93) and near perfect for full-text review ($\kappa = 0.94$).

3.2. Study characteristics

Supplementary file 2 summarises study characteristics. The 35 included studies comprised 26 unique cohorts across 14 countries (11 high-income and 3 upper-middle-income economies) and were published between 2005 and 2024.

A total of 19 239 patients (34% male [$n = 6\,535$]; 53% female [$n = 10\,233$]) were followed from a baseline of 23 017 over a median of 2 years (range: 0.25–15 years). One study did not report patient sex (3%). Mean ($\pm$ SD) age was 55.7 ± 14.5 years. Mean height, body mass, and BMI of were 165.8 ± 4.5 cm, 69.2 ± 8.0 kg, and 26.9 ± 2.5 kg/m², reported in 8, 7, and 23 studies, respectively.

Flexibility and joint ROM were assessed by 33 tests, mostly commonly at the knee ($k = 12$; 2 tests) and hip ($k = 12$; 6 tests), followed by the lumbar ($k = 8$; 3 tests) and cervical spine ($k = 5$; 4 tests).

Fifteen chronic health conditions were represented, most frequently OA ($k = 12$) and axial spondyloarthritis ($k = 7$), followed by primary care cohorts ($k = 4$) and adhesive capsulitis ($k = 2$). All other conditions were represented by single studies ($k = 1$).

3.3. Risk of bias in studies

The risk of bias across all included studies was considered moderate based on a mean score of 1.9 ± 0.4 out of 3, corresponding most closely to a rating of “probably yes.” Three studies (9%) were rated as excellent, 11 studies (31%) good, 19 studies (54%) moderate, and two studies (6%) poor in methodological quality. Key limitations included insufficient documentation of co-interventions that might influence the outcome (89% [$n = 31$]), inadequate cohort follow-up (71% [$n = 25$]), limited confidence in exposure assessment (51% [$n = 18$]), and uncertain assessment of prognostic factors (25% [$n = 9$]). The methodological quality of each study is presented in Supplementary File 3.

3.4. Quantitative synthesis

3.4.1. Self-reported pain, stiffness, and physical function (WOMAC) in patients with osteoarthritis

Flexibility was not associated with self-reported measures of pain, stiffness, and physical function (i.e., the WOMAC) in patients with OA ($r = 0.14$, 95% CI = -0.03 – 0.29 , $p = 0.09$), based on 14 effect sizes from three cohorts (Fig. 2) [52, 56, 62]. A multilevel random-effects model accounted for within-cohort dependency. Heterogeneity was moderate ($\tau^2 = 0.0$; $Q(13) = 105.1$, $p < 0.001$; $I^2 = 44.9\%$). Effect estimates differed by type ($QM(3) = 13.7$, $p = 0.003$): unstandardised regression coefficients were significant (pooled $r = 0.19$, 95% CI = 0.07 – 0.32 , $p = 0.002$), whereas correlations ($r = 0.12$, 95% CI = -0.03 , -0.26) and standardised regression coefficients ($r = 0.08$, 95% CI = -0.05 , 0.22) were not.

There was no evidence of small-study effects (Egger’s test: $QM(1) = 1.13$, $p = 0.25$), and leave-one-cohort-out analyses showed stable estimates ($r = 0.09$ to 0.16), indicating robust findings (Supplementary File

4).

3.5. Narrative Synthesis

3.5.1. Osteoarthritis

Eleven studies (7 cohorts) examined flexibility in relation to total knee arthroplasty, radiographic outcomes, self-reported symptoms (pain, stiffness, physical function), and physical function [42, 46, 48, 52, 61–63, 65, 68, 72, 73].

Total knee arthroplasty (TKA)

Across four studies (2 cohorts), reduced knee extension (flexion contracture) consistently predicted higher TKA risk. Odds increased by 23–34% in smaller cohorts [48, 73] and 6–34% in the OAI cohort [52, 72], with a dose-response effect (up to OR = 3.64 for severe contracture) [52]. Active knee flexion ROM was not associated [48].

Incident radiographic OA and radiographic progression

Evidence from four studies (3 cohorts) was mixed [46, 52, 61, 65]. Limited knee ROM was associated with radiographic progression in some studies [52, 65], while hip ROM showed stronger associations: reduced hip flexion ($\leq 115^\circ$) and internal rotation ($< 20^\circ$) predicted incident or end-stage OA (OR up to 7.13) [46, 61].

Self-reported pain, stiffness, and physical function (The Western Ontario and McMaster Universities Arthritis Index [WOMAC])

Two additional studies not included in the meta-analysis reported inconsistent findings [42, 63]. Composite lower-limb ROM predicted clinical progression [42], whereas individual joint ROM generally did not predict WOMAC outcomes, except for negligible effects for hip flexion [63].

Objectively measured function (10-m timed walk test)

Findings from two studies (1 cohort) were inconsistent [62, 68]. Knee ROM predicted walking performance at 5 years in one study [68], but not consistently across time or joints in the other [62].

3.5.2. Axial spondyloarthritis

Seven studies (6 cohorts) examined associations between flexibility and structural progression, disease activity, function, cardiovascular outcomes, and body mass index (BMI) [44, 47, 50, 53, 54, 66, 67].

Structural and radiographic disease progression

The Bath Ankylosing Spondylitis Metrology Index (BASMI) showed longitudinal associations with radiographic damage in several cohorts [50, 66, 67], though findings varied by model and subgroup.

Individual mobility measures (e.g., lateral spinal flexion) showed more consistent adjusted associations [50].

Compared to chronic low back pain patients without axial spondyloarthritis, those with early axial spondyloarthritis regressed over 2 years on the composite BASMI and some (e.g., occiput-to-wall distance and modified Schober), but not all, BASMI component measures [44].

Measures of disease activity

BASMI and its components were associated with disease activity indices (Bath Ankylosing Spondylitis Disease Activity Index [BASDAI], Ankylosing Spondylitis Disease Activity Score with CRP (ASDAS-CRP]) in two studies (1 cohort) over 2 [54] and 5 years [50].

Functional limitations

Greater spinal and hip flexibility were associated with better functional outcomes (Bath Ankylosing Spondylitis Functional Index [BASFI], Health Assessment Questionnaire modified for spondyloarthropathies [HAQ-S]) over 1.5 years in a single study, although some associations attenuated after statistical adjustment [53].

Major adverse cardiovascular events (MACE)

Greater lumbar flexibility (modified Schober test) was associated with lower risk of major adverse cardiovascular events (acute coronary syndrome, stroke, cardiovascular death, or heart failure) by 42% (HR = 0.58, 95%CI = 0.38, 0.90) [47].

Body mass index (BMI)

Carvalho et al. [50] observed that associations with BMI were inconsistent across flexibility measures.

3.5.3. Primary care patients

Four studies (one cohort) examined associations between flexibility and self-reported mobility modifications in older primary care patients (aged ≥ 65 years) [23, 40, 57, 71]. Reduced knee flexion predicted decline in advanced mobility (OR ≈ 2.0) and persistent functional limitation [23, 71]. Ankle ROM showed limited or subgroup-specific associations [57, 71].

3.5.4. Adhesive capsulitis

Two studies (1 cohort) observed that shoulder ROM measures (flexion, abduction, and external rotation) were associated with pain (Visual Analogue Scale [VAS]) and disability (the Disabilities of the Arm, Shoulder and Hand [DASH] questionnaire) at 9-months [51, 70]. However, only external rotation predicted quality of life in two of the eight subscales of the 36-Item Short Form Health Survey (SF-36) [70].

3.5.5. Chronic low back pain

Baseline hip ROM measures (extension, external rotation, and abduction) predicted physical function (e.g., repeated chair rise performance, gait speed) in a single study of older adults with chronic low back pain [55]. However, hip abduction was not associated with functional endurance (6-Minute Walk Test) or disability (Quebec LBP Disability Questionnaire) over 12 months.

3.5.6. Chronic neck pain

A single study reported no association between active cervical ROM and pain (Verbal Numerical Pain Scale [VNPS]) or disability (Northwich Park Pain Questionnaire [NPQ]) at 6-months in patients with chronic neck pain [49].

3.5.7. Plantar fasciopathy

One study reported no association between baseline ankle dorsiflexion and pain intensity (11-point numerical rating scale) or function (ADL subscale of the FAAM [Foot and Ankle Ability Measure] questionnaire) at 4 months in patients with plantar fasciopathy [45].

3.5.8. Rheumatoid arthritis

The Escola Paulista de Medicina–Range of Motion (EPMROM) scale—an index measures based on 10 bilateral motions in 7 joints measured with a goniometer—was not associated with basic activities of daily living (Barthel index) and mobility (rated by caregivers) at 3-years in patients with rheumatoid arthritis [60].

3.5.9. Systemic lupus erythematosus (SLE)

The back scratch test was not associated with atherosclerotic plaque 3 years later in one study of female patients with systemic lupus erythematosus (SLE) [43].

3.5.10. Type I diabetes

Declines in wrist and finger flexion were relatively larger in patients with type I diabetes over 15 years compared with healthy controls [58].

3.5.11. Type II diabetes

A single study reported that metatarsophalangeal joint mobility predicted ulceration in male, but not female, patients with type II diabetes [69].

3.5.12. Schizophrenia

The sit-and-reach test was not associated with cognitive performance (attention, hand dexterity, working memory) in patients with schizophrenia [64].

3.5.13. Intellectual disabilities

Modified back saver sit and reach test performance was not associated with basic activities of daily living (Barthel Index) and mobility (caregivers rated) in adults with intellectual disabilities [59].

3.5.14. Dementia

Poorer performance in the right back scratch test was associated with a 6% increased odds of rapid cognitive decline—defined as a ≥ 2 point decline in the Mini Mental State Examination [MMSE] score—over 12 months in patients with dementia (OR = 1.06; 95%CI = 1.01, 1.11) [41]. In contrast, neither the left back scratch or sit-and-reach tests predicted future cognitive decline.

3.6. Certainty of evidence

The certainty of evidence was classified as moderate for the WOMAC in elderly patients with hip and/or knee OA, with evidence downgraded one level due to risk of bias. Supplementary File 5 contains the full details of the GRADE assessment. The GRADE approach was also applied to outcomes that were summarised narratively when two or more studies reported on that outcome [74]. For patients with osteoarthritis, there was a high certainty of evidence that knee flexion contracture predicts a higher risk of TKA, while the certainty of evidence was very low that reduced hip and knee ROM predicted radiographic progression of OA and slower gait speed. For patients with axial spondyloarthritis, there was very low certainty of evidence that reduced flexibility was prospectively associated with structural and radiographic disease progression, but moderate certainty of evidence supporting a prospective association between greater flexibility and better measures of disease activity. There was low certainty of evidence that reduced knee flexion predicts mobility and functional limitations in primary care patients aged 65 years and older with self-reported mobility modifications, and low certainty of evidence that reduced shoulder ROM predicts pain and disability in patients with adhesive capsulitis.

4. Discussion

This study systematically reviewed, and where possible meta-analysed, the prospective association between flexibility and health outcomes among adults with chronic health conditions. Substantial heterogeneity across clinical conditions, flexibility measures, and health outcomes limited quantitative synthesis to a single meta-analysis, which found a moderate certainty of evidence of no association between flexibility and self-reported pain, stiffness, or function in patients with hip and/or knee OA. Beyond OA and axial spondyloarthritis, longitudinal research was noticeably sparse, highlighting critical gaps that limit the translation of flexibility assessment into routine clinical practice. Coupled with the lack of standardisation in flexibility assessments, these findings underscore the pressing need for high-quality, condition-specific prospective cohort studies to establish the clinical relevance of flexibility.

OA and axial spondyloarthritis were the most frequently studied clinical conditions. In patients with knee OA, reduced terminal knee extension (flexion contracture) was consistently associated with subsequent total knee replacement [48, 52, 72, 73], whereas active knee flexion ROM was not [48]. Mechanistically, avoidance of terminal extension in patients with pain—associated with maximal tibiofemoral congruency [75, 76]—may reflect pain adaptation. Importantly, knee extension is critical during the midstance phase of the gait cycle for stability [77] and for optimal quadriceps muscle activation [78, 79], suggesting that its preservation may help mitigate medial knee loading and slow cartilage degeneration [80–82].

Restricted ROM may also increase the metabolic cost of gait [83, 84], discouraging incidental movement and contributing to a vicious cycle of physical inactivity, weight gain, and deconditioning. Supporting this, Pisters et al. [68] observed that reduced knee extension (and flexion) predicted slower gait speed 5 years after baseline assessment. Clinically, these findings indicate that knee extension should be prioritised in routine assessment, and targeted interventions aimed at improving knee extension may have functional and structural benefits, although prospective interventional studies are needed. Consistent with this, knee flexion contracture also predicted incident and progressive radiographic OA according to Kellgren–Lawrence grading [52].

At the hip, internal rotation did not predict incident hip OA [46, 61] but was associated with progression towards end-stage hip OA [46]. Hip flexion, on the other hand, predicted both incident and end-stage hip OA [61]. Both movements approach the closed-packed positions of the hip joint [75, 76], suggesting that avoidance of end-range loading may reflect or influence disease progression [85–87]. Although our meta-analysis showed no association between flexibility and WOMAC outcomes, the analysis was likely underpowered, particularly for pain, which was assessed in only a handful of studies [56, 62]. Supporting a potential relationship, Yusuf et al. [42] observed that lower total hip and knee ROM predicted worsening pain and physical function 6 years later in a separate cohort. Unlike the knee, hip flexion was not associated with future gait speed [62, 68], probably because gait does not require end-range hip flexion [88, 89]. Nevertheless, the findings of the current review suggest that assessing hip flexion—and to a lesser extent hip internal rotation—remains clinically important to identify patients at risk of OA progression and to inform early intervention strategies.

Strong evidence supports the BASMI as a longitudinally marker of structural damage and disease activity [44, 50, 54]. The predictive value of the BASMI appears to exceed that of individual components [44, 50], suggesting that composite, region-specific assessments better capture clinically meaningful changes. This finding is consistent with the diffuse spinal involvement characteristic of the disease [90, 91]. These findings support the use of BASMI in routine clinical monitoring, as regular assessment may guide treatment decisions and help identify patients at risk of structural deterioration or functional decline.

A key finding of the review was the lack of longitudinal evidence supporting flexibility as a predictor of future health in patients with major chronic conditions. No prospective studies were identified investigating the association between flexibility and health in patients with cardiovascular disease, cancer, chronic respiratory diseases (e.g., chronic obstructive pulmonary disease [COPD], asthma), mental health disorders, obesity, osteoporosis, or kidney disease, highlighting a major gap in research with direct clinical implications. Only one study investigated flexibility in people with type II diabetes [69] despite its global burden [92, 93] and plausible mechanistic links to musculoskeletal stiffness via glycation and neuropathy [94, 95]. Likewise, only one study was identified for chronic low back and neck pain [49, 55] despite their high disability burden [96, 97]. Overall, there is a profound gap in prospective flexibility research across the most highly prevalent chronic health conditions, representing a critical opportunity for future research.

4.1. Limitations

While this review considered a wide range of clinical populations, our exclusion of post-surgical populations avoided the confounding effects of surgery on ROM but limited applicability to common groups (e.g., joint replacement, ACL reconstruction, post-mastectomy). Congenital conditions (e.g., hypermobility spectrum disorder (HSD), Ehlers-Danlos syndrome (hEDS)) were also excluded despite known associations with adverse health outcomes [98–102]. Restricting our search to articles published from 2005 onwards—to balance comprehensiveness and practicality while maintaining data recency and applicability of evidence—may have reduced the study pool for meta-analysis. Additionally, heterogeneity and limited data precluded formal certainty assessment beyond WOMAC outcomes in patients with OA, reinforcing the need for high-quality prospective studies.

4.2. Recommendations for future research and practice

The BASMI provides a clinically useful model for condition-specific, multi-joint flexibility assessment. Flexibility is joint specific and cannot be adequately captured by a single test [14]. Flexibility assessments, therefore, should align with underlying pathology (e.g., shoulder ROM in cases of suspected adhesive capsulitis, or hip and lumbar spine ROM in individuals with chronic low back pain). For systemic or multi-joint conditions, assessing flexibility across multiple bodily regions offers a more comprehensive evaluation. Current practice often relies on single, poorly justified tests (e.g., the sit-and-reach test for patients with schizophrenia, the back scratch in patients with dementia) [41, 64], limiting interpretability and clinical justification. Developing and validating condition-specific composite measures is a research priority, and these may better clarify the predictive utility of flexibility and inform clinical decision making.

4.3. Implications

Despite a lack of higher-quality longitudinal studies, targeted flexibility assessment may inform clinical care in select chronic health conditions. In OA, knee extension and hip flexion ROM predict total joint replacement risk and functional decline, while in axial spondyloarthritis, the BASMI—particularly lateral spinal flexion—correlates with structural damage, disease activity, and functional limitations. Single tests, such as the sit-and-reach or back scratch, were generally not associated with health outcomes in individuals with schizophrenia, dementia, or SLE, possibly suggesting that flexibility is most informative when assessed within a condition-specific, multidimensional framework. The paucity of longitudinal evidence across those with prevalent chronic health conditions underscores the urgent need to establish whether flexibility meaningfully predicts health outcomes to justify routine clinical use.

In summary, while reduced flexibility—particularly joint-specific limitations such as knee extension or hip rotation—may be associated with disease progression or functional decline for certain musculoskeletal conditions, such as osteoarthritis, the evidence is inconsistent, and its health-related prognostic value in clinical populations remains unclear and limited. The general distribution and direction of evidence is summarised in Fig. 3.

5. Conclusion

Flexibility remains an under-explored marker of future health in patients with chronic health conditions. While knee and hip ROM in OA and BASMI components in axial spondyloarthritis show some prognostic value for structural progression, functional status, and disease activity, single-test flexibility measures like the sit-and-reach or back scratch have generally not been associated with health outcomes in other conditions. Methodological heterogeneity and sparse longitudinal data limit broader conclusions, highlighting an urgent need for robust, condition-specific longitudinal studies to determine whether flexibility assessments can meaningfully guide clinical decision-making and inform targeted interventions, and justify their inclusion in standard health-related fitness frameworks.

Declarations

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Conflicts of interest Lewis Ingram, Grant Tomkinson, Bethany Gower, Noah d'Unienville, Terry Boyle, Justin Lang, and Hunter Bennett declare that they have no conflicts of interest.

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Data availability The data and materials necessary to reproduce the findings reported in this manuscript are available at <https://osf.io/23s5y/files/osfstorage>

Author contributions LI, GT, and HB contributed to the conception and design of the review and meta-analysis. LI and HB performed the initial search of databases. LI, GT, BG, ND, JL, and HB screened and selected the eligible studies. LI performed the data extraction, which was verified by BG. LI, BG and ND assessed the risk of bias of the included studies. LI and HB performed the GRADE analysis. HB performed the statistical analysis, which was verified by TB. LI drafted the manuscript. All authors reviewed, provided critical revisions, refined, and approved the final manuscript.

Disclaimer The content and views expressed in this article are those of the authors and do not necessarily reflect those of the Government of Canada.

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Figures

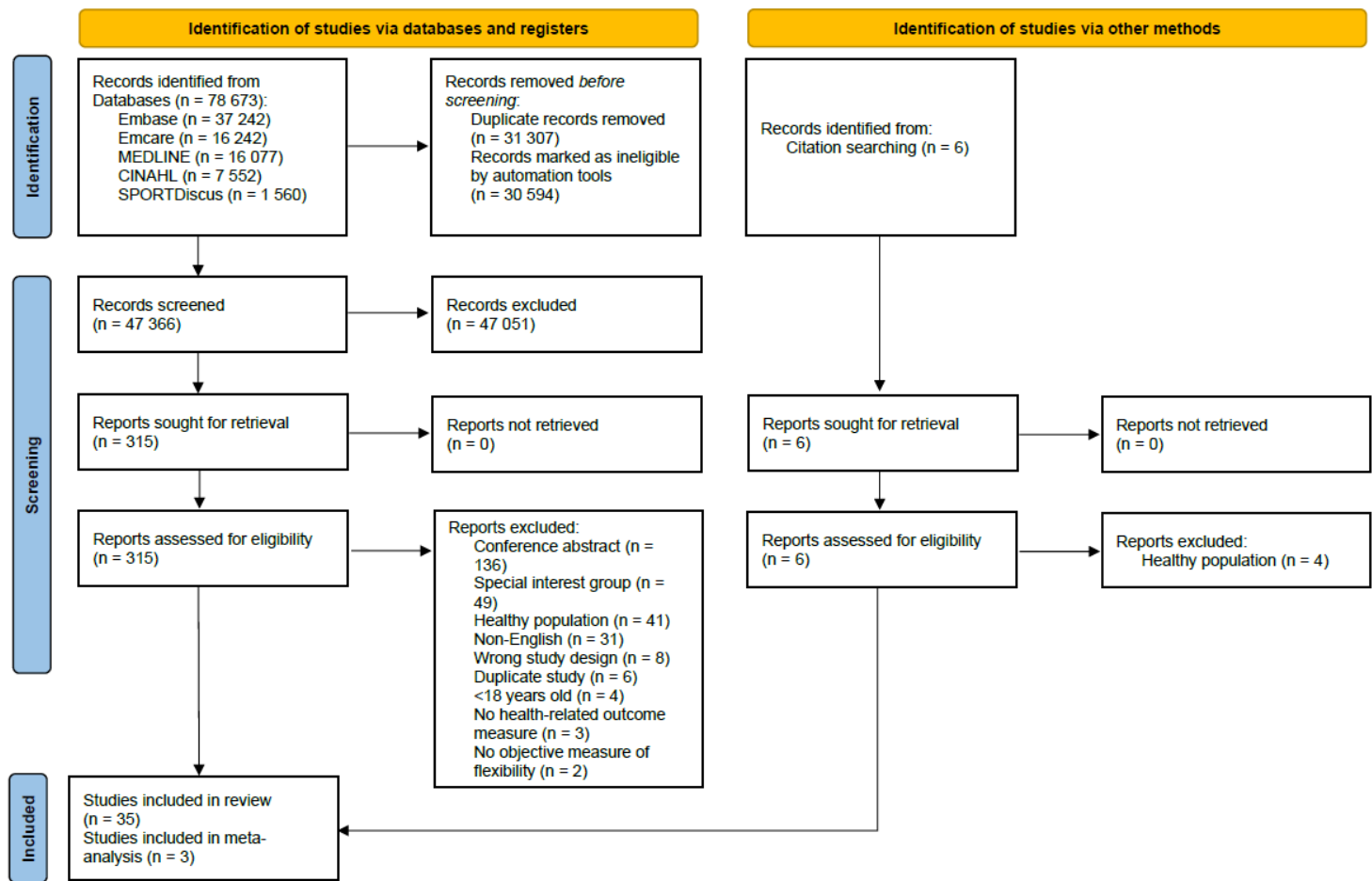


Figure 1 Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flowchart showing the different stages of the search and study selection process

Forest Plot - Flexibility and WOMAC

Red line = pooled r (0.135)

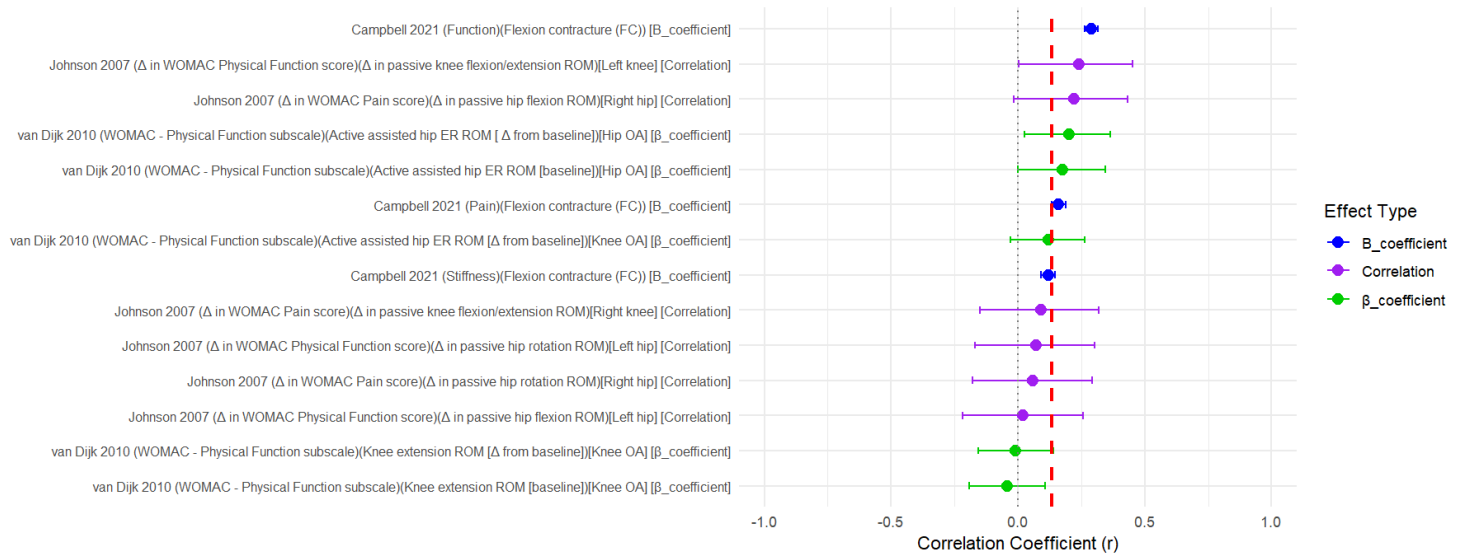
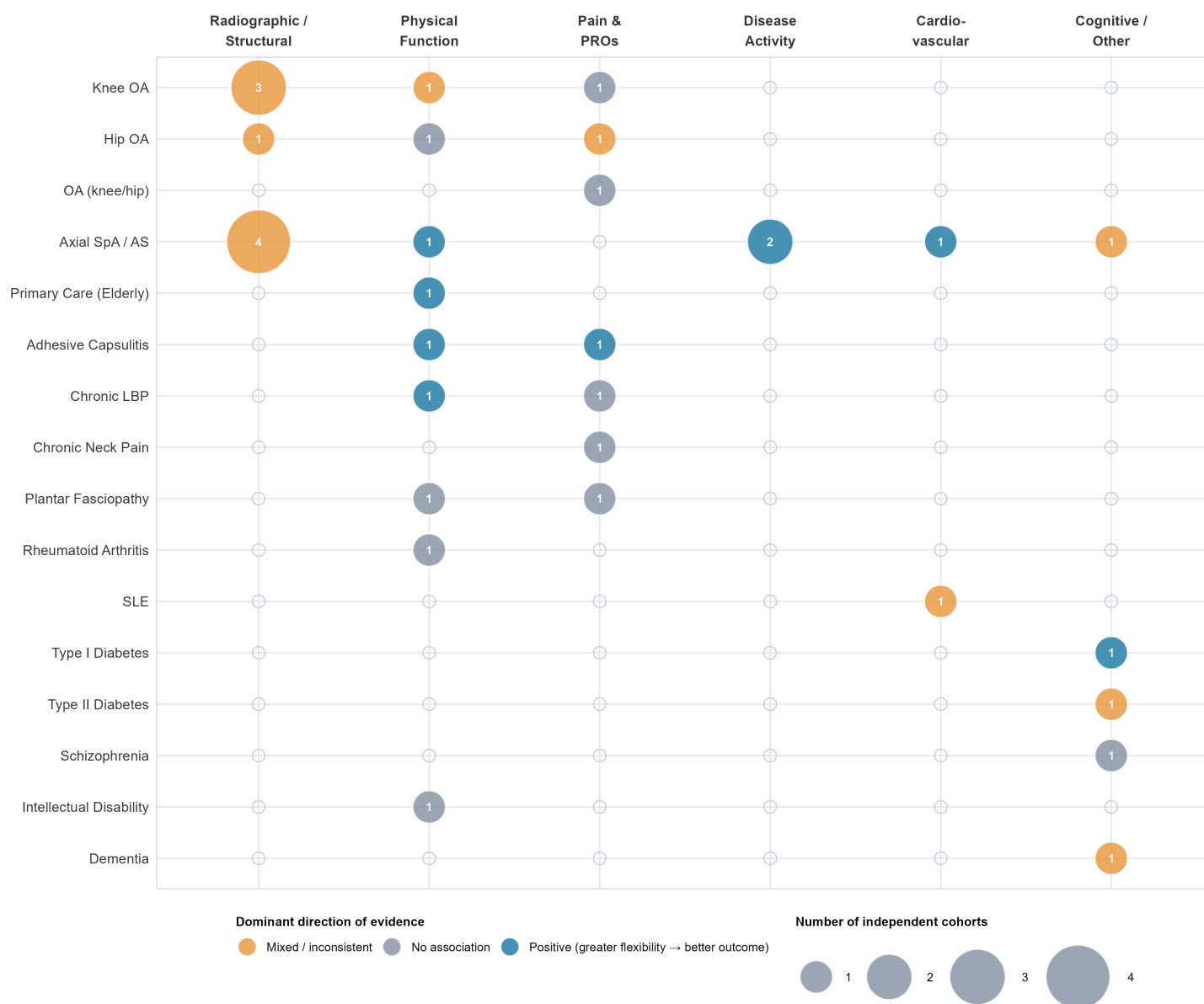


Figure 2

Correlation coefficients () for the prospective association between flexibility at baseline and self-reported pain, stiffness, and function as measured by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) in patients with knee and/or hip osteoarthritis. $-1 \leq r \leq 0$ indicates greater flexibility is prospectively associated with a reduced risk of self-reported pain, stiffness, and function, while $0 \leq r \leq 1$ indicates an increased risk

Flexibility and health in clinical populations

Bubble size = number of independent cohorts. Colour = dominant direction of evidence ($\geq 70\%$ threshold). Open circles = no studies identified.



Direction classified as dominant if $\geq 70\%$ of findings share the same direction; otherwise Mixed.
Bubble size reflects unique study cohorts.
Population groups are collapsed from specific study populations.

Figure 3

General summary of flexibility and health outcomes across clinical populations. Bubble size indicates the number of independent cohorts for each broad outcome category. Bubble colour indicates the dominant direction of evidence ($\geq 70\%$ threshold): amber = mixed or inconsistent findings; grey = no association; teal = positive association (greater flexibility associated with better outcomes). patient-reported outcomes, osteoarthritis, spondyloarthritis, ankylosing spondylitis, low back pain, systemic lupus erythematosus.

Supplementary Files

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- [SupplementaryFile1.Searchstrategy.docx](#)
- [SupplementaryFile2.Characteristicsofincludedstudies.docx](#)
- [SupplementaryFile3.Riskofbiasassessment.docx](#)
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- [SupplementaryFile5.GRADEanalysis.docx](#)