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Non-surgical interventions for arthrofibrosis following knee joint replacement: A systematic review

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Abstract

Objective: To evaluate the effectiveness of non-surgical interventions for knee stiffness or arthrofibrosis following knee replacement surgery.

Data sources: Ovid MEDLINE, Ovid Embase, Cochrane Central Register of Controlled Trials (CENTRAL), and Cumulative Index to Nursing and Allied Health Literature (CINAHL)were searched from database inception to October 2024.

Review methods: All studies of non-surgical interventions (versus any/no comparator) for adults who developed knee stiffness or a diagnosis of arthrofibrosis following knee replacement were included. Selection, quality appraisal and extraction were completed in duplicate. Results were synthesised narratively. The risk of bias was assessed, and GRADE criteria were used to evaluate evidence quality.

Results: Sixteen studies were included, comprising two randomised-controlled trials (n = 76), one non-randomised controlled trial (n = 35), seven cohort studies (n = 352) and six case studies (n = seven). Interventions varied widely including exercise, manual therapy, mechanical devices, and education. Improvements in knee range of movement were reported with some demonstrating functional gains >110° of knee flexion, but the evidence was of low quality. Limited reporting of intervention descriptions, patient-relevant outcomes including function and pain, and longer-term follow-up hindered comprehensive evaluation.

Conclusion: The review highlights the heterogeneity of interventions, emphasising the need for standardised reporting. While some studies showed promise, the lack of control groups, small sample sizes, and

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varied follow-up durations limit conclusive findings. There is insufficient evidence to support any specific non-surgical interventions for arthrofibrosis post-arthroplasty. Further research should be a priority.

Keywords
Arthrofibrosis, knee joint replacement, physiotherapy, systematic review

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Introduction

Total knee replacement surgery is a highly effective treatment for end-stage osteoarthritis, with over 100,000 primary procedures performed in the United Kingdom (excluding Scotland) in 2022.[1] However, as many as 18% (around 18,000 cases) of all knee replacement surgeries are affected by post-operative stiffness, ranking as the second most common reason for hospital re-admission following infections.[2–4] Severe stiffness due to arthrofibrosis occurs when an abnormal inflammatory response leads to excessive collagen production and scar tissue formation.[5,6] The resulting restrictions in range of movement, particularly knee flexion, can be debilitating; using a standard chair and negotiating stairs requires 90–120° of knee flexion, so even minor restrictions can have a profound impact on an individual's mobility and function, ultimately leading to a loss of independence.[7]

Physiotherapy is typically the first-line treatment for arthrofibrosis, but there is significant variability in what care patients receive with no clinical guidelines for what this should encompass.[5,8] Those who do not improve with physiotherapy are often referred for manipulation under anaesthetic to 'break' the adhesions or other surgical approaches. Most systematic reviews on this topic focus on the efficacy and timing of the manipulation under anaesthetic.[9,10] Though generally considered effective, some adverse events during the procedure include rupture of the knee extensor mechanism and fractures around the joint replacement.[11] More significantly, however, manipulation under anaesthetic is linked to a five-fold increased risk of revision surgery within six years, equating to poorer outcomes and increased costs.[12,13]

Existing non-surgical interventions for arthrofibrosis management include exercise, massage, stretching devices, splints, neuromuscular stimulation, education, and multi-modal physiotherapy. A systematic review of medical stretching devices across 13 studies of mixed study design reported improvements in knee range of movement with the use of these devices, but heterogeneity across the studies precluded a meta-analysis.[14] Additionally, variation in the reporting of range of knee movement (mean increases in flexion/extension and/or total range) makes interpretation difficult. While only a limited number of interventions have undergone testing in randomised controlled trials, there is some evidence indicating that non-surgical interventions may improve knee flexion and reduce the need for further surgery.[15,16]

The primary objective of this review was to evaluate the effectiveness of non-surgical physiotherapeutic interventions for arthrofibrosis/knee stiffness following knee joint replacement on range of movement. Secondary objectives were to determine the effectiveness for other reported outcomes and evaluate the reporting of intervention descriptions.

Methods

This systematic review was registered with the International Prospective Register of Systematic Reviews (CRD42022340090), conducted using established processes (Cochrane Handbook V6.1)[17] and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (available in Supplemental file 1).[18]

Search strategy

Articles were identified by electronic searching of the following databases:

(a) Cochrane Central Register of Controlled Trials (CENTRAL)
(b) Cumulative Index to Nursing and Allied Health Literature (CINAHL)
(c) Ovid EMBASE
(d) Ovid MEDLINE including ahead-of-print and in-process & other non-indexed citations
(e) First 100 citations on Google Scholar

The databases were searched from their inception up to August 2023 and updated in October 2024. Additionally, the reference lists of included studies and pertinent reviews were manually examined to ensure comprehensive coverage of eligible studies.[14,19]

The search strategy involved two main categories of keywords: those related to participants and those relating to the interventions. These categories were then combined using Boolean operators (see Supplemental file 2).

Eligibility criteria

Inclusion criteria are outlined in Table 1. Studies involving any surgical interventions, including manipulation under anaesthetic alone, and those including patients with neurological or blood disorders were excluded. Language restrictions were not applied; non-English papers were assessed and, if necessary, translated into English using university-based translation services.

Study selection and screening process

Results from the searches were imported into EndNote bibliographic software (Thomson Reuters, Philadelphia, PA, USA), and duplicates were eliminated. The study selection process involved three reviewers (MH, SG and BS) using Covidence software to determine agreement. All studies were screened independently by two reviewers using the title and abstract, and subsequently, where a decision could not be made, using full text. In case of disagreements, a third reviewer was available to facilitate resolution.

Data extraction

A tailored data extraction sheet was developed and refined after pilot testing on a randomly selected

Table 1. Inclusion criteria.

Study design	Any study design including randomised controlled trials, cohort studies, case-control studies, observational studies, case series and case reports.
Participants	Adults who developed knee stiffness or had a diagnosis of arthrofibrosis or contracture following knee replacement for osteoarthritis.
Interventions	Any of the following: • Passive intervention (e.g., stretching programme, manual techniques, continuous passive motion) • Active rehabilitation task (e.g., active or strengthening exercise, functional task practice) • Adjunctive therapies or devices (e.g., electrical stimulation, splinting) • Training and education (to carers or other healthcare professionals)
Comparator	Any of the following: • Any other intervention • No intervention • Usual care
Outcomes	The primary outcome was the range of movement at the knee joint. Other measures included pain, measures of function, activity or participation, quality of life, and patient satisfaction. Other data such as progression to manipulation under anaesthetic, adverse events and costs were included where available.

subset of studies. Data extraction was carried out by four reviewers (MH, SG, BA, and BS). Each publication's data were extracted by one reviewer, with a sample validated by independent extraction. Disagreements were resolved by discussion with another reviewer in the group.

The following data were extracted: author(s), year of publication, study design, location, sample size, eligibility criteria, population (count, surgery type, demographics, allocation as applicable), setting, intervention description (according to the Template for Intervention Description and Replication checklist),[20] duration, resource requirements, intervention compliance, comparator description (as applicable), type and timing of outcome measures of interest (function, activity, participation, adverse events, economic evaluation), adverse events, analytical approach (handling of missing data as applicable), and summary statistics and/or effect estimate/s.

Assessment of methodological quality

Four review authors conducted independent assessments of each included study to evaluate their risk of bias, guided by the Cochrane Handbook of Systematic Reviews of Interventions.[17] Bias assessment for randomised controlled trials used the Cochrane risk of bias tool v2.[21] This tool assesses the risk of bias using five domains for randomised controlled trials: bias arising from the randomisation process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in the measurement of the outcome, and bias in the selection of the reported result. Studies were assigned an overall high risk of bias if the trial was judged to be at high risk of bias in at least one domain or the trial was judged to have some concerns in multiple domains in a way that substantially lowered the confidence in the result. Studies were assigned 'some concerns' if the trial was judged to raise some concerns in at least one domain for the result, but not to be at high risk for any domain. Studies were assigned as 'low risk of bias' when all domains were judged to be low risk of bias.

In the case of observational studies, including cohort and case-control studies, bias was assessed using the modified Newcastle-Ottawa Scale, which considers the risk of bias in selection, comparability, and exposure/outcome.[22,23]

The Risk of Bias in Non-randomised Studies of Interventions tool was employed for non-randomised studies which considers risk of bias across seven domains: confounding, participant selection, intervention classification, intervention deviations, missing data, outcome measurement, and selection of reported results.[24]

The Joanna Briggs Institute critical appraisal checklist for case reports was used for case reports.[25] It consists of a checklist with items covering the description of the patient and their history, diagnostic tests, intervention description, clinical changes post-intervention, adverse events and clinical message.

Analysis

We were unable to conduct a meta-analysis due to the diversity of interventions, comparators, and study designs. Therefore, we conducted a narrative synthesis based on study design where the outcome of primary interest was knee range of movement, and additional secondary outcomes are also reported.

In cases where there was sufficient data available, examinations of interventions based on their type were conducted. For instance, interventions were categorised by mechanical stretching devices, splints, or multi-component interventions. This allowed analysis and comparison of interventions within these specific categories. Finally, we reviewed the interventions' descriptions using the Template for Intervention Description and Replication checklist to examine the key features of the interventions.[20]

Strength of the evidence

The strength of the evidence was evaluated using the Grading of Recommendations Assessment, Development, and Evaluation approach.[26] Each outcome initially started at a 'high' level of evidence and was subsequently downgraded, if necessary, based on four domains: Study limitations,

Inconsistency, Indirectness, and Imprecision. The fifth domain 'Publication Bias' was not assessed, as this is recommended only when ten or more studies are included in a meta-analysis.

Results

Database searches retrieved 6314 articles, and following the removal of duplicates, 4338 articles underwent screening for inclusion. After screening titles and abstracts, 162 full-text articles were evaluated for eligibility, resulting in the exclusion of 145 articles. The study selection process and reasons for exclusions are shown in the PRISMA flow chart (Figure 1). A total of 16 articles were included in the review.

Characteristics of the included studies

The characteristics of the 16 included articles are summarised in Table 2. Of the included articles, two were randomised-controlled trials (n = 76) with 23.0% males and a mean age of 63.5 years,[15,16] one was a non-randomised controlled trial (n = 35) with 42.9% males and a mean age of 64.9 years,[27] seven were cohort studies (five were prospective in design,[28–32] three were retrospective[33,34] (n = 329) with 37.2% males and a mean age of 63.2 years, one study did not report sex/age,[29] and six were case reports with seven participants, four of whom were male, with a mean age of 55.3 years.[35–40]

Assessment of methodological quality and strength of evidence

Randomised-controlled trials

There were some concerns for both randomised controlled trials (Figure 2) that exhibited bias risks related to insufficient detail in randomisation and concealed allocation as well as a lack of assessor blinding when using handheld goniometry. In the Papotto et al. trial,[16] one participant changed groups, but this was unlikely to have a major effect on the outcome. Both studies were low risk for selective reporting and missing outcomes.

Non-randomised trials

The non-randomised controlled trial exhibited a risk of bias due to insufficient detail regarding confounding variables and inadequate adherence to the control intervention.[27]

Cohort studies

Risk of bias assessment for the seven cohort studies, conducted with the modified Newcastle-Ottawa Scale, is summarised in Table 3. In general, these cohort studies lacked sufficient detail regarding the selection of the non-exposure or treatment group.[28–30,32] Some of the studies exhibited bias risks due to non-independent blinded assessors[29–31,34] and a low follow-up rate of participants.[29,33]

Case studies

The Joanna Briggs Institute Critical Appraisal Checklist for case reports can be found in Table 4. Overall, the case studies included in this review, which exclusively examined patients exposed to the intervention, exhibited a high level of methodological quality. However, one study lacked comprehensive participant demographic information,[39] another inadequately described the intervention,[38] and two studies omitted details on adverse events.[39,40]

Strength of evidence

Grading of Recommendations Assessment, Development, and Evaluation was carried out for range of movement, function and future manipulation under anaesthetic (Table 5). Pain and other outcomes were not formally assessed due to very low levels of reporting. The quality of evidence was rated as very low for all outcomes due to trial design limitations, heterogeneity, wide variety of interventions and low participant numbers.

Intervention protocols

The included interventions were frequently complex in nature, and they are described in detail in Supplemental file 3 using the Template for Intervention Description and Replication checklist.[20] The intervention components have been synthesised into key intervention domains:

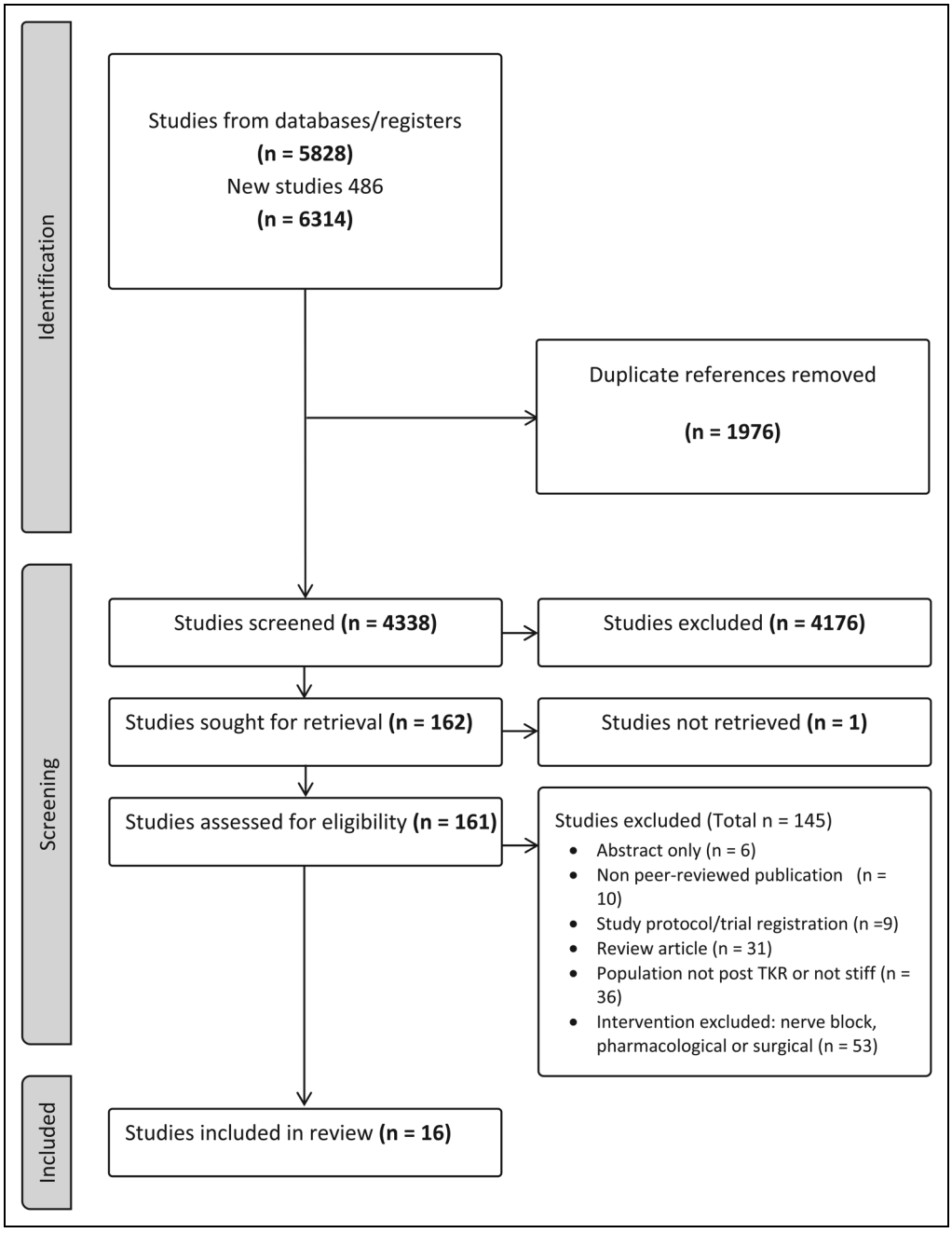

Figure 1. PRISMA flow diagram of selection process.

Exercise; Manual therapy techniques; Use of mechanical devices and splinting; and Other adjuncts. Most studies investigated at least one of these components.

Table 2. Characteristics of included studies.

Author, year of publication and study location	Study design, duration, sample (n)	Eligibility criteria	Exclusion	Details of knee surgery undertaken	Intervention group (IG)	Comparator group (CG)	Outcomes reported	Primary findings
Aspinall, 2020 [41] UK	Non-randomised controlled study 8 weeks n = 35	Primary TKR in past 12 months. Post knee surgery arthrofibrosis defined as <70° flexion.	Post malignancy or knee trauma. Leaking wounds or infected joints, rheumatoid arthritis or osteoporosis, long-term steroid treatment or if the clinician felt the patient was at risk of post-operative fracture. Fall outside weight limits (44 kg to 159 kg).	All TKRs for OA. Not described in detail.	Standard physiotherapy plus the STAK® tool and self-directed stretching.	Standard physiotherapy	Knee ROM (total range), WOMAC, OKS	Mean overall knee ROM increased by 30° in the IG compared to 8° in the CG $p < 0.0005$. WOMAC increased by 19 points in the IG versus 3 points in the CG OKS increased by 8 points in the IG versus 3 points in the CG $p < 0.0005$
Behrns, 2019 [38] USA	Case report 10 weeks n = 1	NA	NA	TKR. Not described in detail.	3-stage rehabilitation programme.	NA	Knee ROM (flexion), KOOS	Knee flexion increased from 82° to 134°. KOOS score decreased from 24 to 5 out of a possible 27.
Bhave, 2016 [39] USA	Case-report 9 weeks n = 1		Astym® treatment	TKR. Not described in detail.	Astym® therapy – soft tissue therapy performed by the topical application of a series of hand-held instruments.	NA	Active and passive knee ROM, patient global rating	Knee extension improved from −30° active knee extension (−25° passive) to 5° both active and passive Knee flexion improved from 100° (active and passive) to 110° active and 115° passive. Global rating of improvement: 7/10.
Bonutti, 2010 [28] USA	Prospective Cohort	Failed standard postoperative physical therapy.	Malalignment, impingement, joint infection, heterotopic	Not provided.	JAS Knee Device©. Median duration of 7 weeks of use.	Nil	Active knee ROM, (flexion,	Median improvement for flexion: 19° (range 5–80); for

(Continued)

Table 2. (Continued)

Author, year of publication and study location	Study design, duration, sample (n)	Eligibility criteria	Exclusion	Details of knee surgery undertaken	Intervention group (IG)	Comparator group (CG)	Outcomes reported	Primary findings
	22 months n = 25	Defined as active flexion of less than 90° and/or a flexion contracture that negatively impacted function.	ossification or other osseous deformities.				extension and total)	extension was 7° (range 4–18). Total range increased from 25° (range, 8–82) to 105° (range, 61–137).
Chughtai, 2016 [33] USA	Retrospective Comparative Cohort 6 months n = 57	Patients who had an MUA following a TKR performed between January 2013 and December 2014.	Patients who had received both interventions.	Not provided.	Innovative Multimodal Physical Therapy Protocol: 30 mins of one-on-one supervised therapy, including bracing, neuromuscular electrical stimulation, hands-on manipulation and mobilisations, and exercise. Including Astym® therapy – soft tissue therapy, performed by the topical application of a series of hand-held instruments.	Week 1–6: physical therapy focusing on: passive ROM, mobility free walking, quads strength. Week 4–8, focusing on normal everyday activities with sit to stand exercises, stairs, balance, isometric exercises, stationary bike, manual therapy.	Knee ROM flexion and extension, optimal ROM (>110 flexion and 5 extension), incidence of MUA.	Baseline data not reported, but both groups were similar. Greater knee flexion in the IG 116° versus 106° in the CG $p < 0.005$ 100% of patients achieved optimal flexion in the IG versus 50% in the CG. Lower incidence of MUA in the IG: 0% versus 20% in the CG.
Chughtai, 2016 [29] USA	Prospective Cohort 12 months n = 23	Persistent recalcitrant knee stiffness despite a standard rehabilitation of at least 6-weeks. Plus at least one failed MUA.	Not provided.	Not provided.	Astym® therapy – soft tissue therapy performed by the topical application of a series of hand-held instruments.		Active and passive knee ROM, knee society score	Mean flexion improved from 70° to 105° ($p < 0.0001$). Improvement in Knee Society objective scores (80 vs 57 points) and functional scores 80 vs 54 points).
Dailey, 2020 [40] USA	Case report 9–10 weeks n = 1			Not provided.	Focused physical therapy.	NA	Knee ROM flexion, single leg balance, lower	Knee flexion increased from 48° to 65 ° post-MUA and 116° post-rehabilitation.

(Continued)

Table 2. (Continued)

Author, year of publication and study location	Study design, duration, sample (n)	Eligibility criteria	Exclusion	Details of knee surgery undertaken	Intervention group (IG)	Comparator group (CG)	Outcomes reported	Primary findings
							extremity functional scale (LEFS)	Single leg balance increased from 7 to 20 s. LEFS improved from 28 to 80 points.
Silva, 2018 [32] **Brazil**	Pre-post intervention study single treatment duration n = 33	Flexion contracture of at least 5°	Cognitive impairment, extrapyramidal syndrome, prior surgical procedures on the knee, revision TKA, complex regional pain syndrome, acute infection or deep venous thrombosis, scar dehiscence, implant failure or periprosthetic fracture, rheumatoid arthritis, Charcot arthropathy and motor neuron diseases.	The most common implant utilised was the posterior stabilized type (90.9%), with a rotatory platform (70%) and a knee medial parapatellar approach (94%). All implants were cemented.	Myofascial release. targeting the gluteal fascia, posterior fascia lata, posterior crural fascia and plantar fascia.		Total knee ROM, pain and muscle electrical activity (biceps femoris)	Increase in overall ROM of 5.7° (SD 63.3) from 54.7° to 60.4°.
Finger, 2008 [36] **USA**	Case report 12 weeks n = 1			Not provided.	Dynamic splinting combined with physical therapy.	NA	Active knee extension	Active knee extension improved from −20° to −12°
Jansen, 1996 [35] **USA**	Case report 4 weeks n = 1			Not provided.	JAS splint.	NA	Knee extension	Knee extension improved from −23° to −6°
Karam, 2011 [37] **USA**	Case report 2 weeks n = 2				Hinged cast brace: adjustments were performed every four to seven days in an attempt to increase each patient's knee extension; after achieving the desired point, it is	NA	Knee ROM extension and flexion	Patient 1. ROM increased from 15–90° (extension -flexion) to 3–110° Patient 2. ROM increased from 15–110°

(Continued)

Table 2. (Continued)

Author, year of publication and study location	Study design, duration, sample (n)	Eligibility criteria	Exclusion	Details of knee surgery undertaken	Intervention group (IG)	Comparator group (CG)	Outcomes reported	Primary findings
					maintained for another one to two weeks with full weight bearing			(extension -flexion) to 3–115°
McGrath, 2009 [30] USA	Prospective Cohort 18 months n = 47	Patients treated between July 2003 and June 2007 with flexion contractures treated with a custom-moulded knee device and physical therapy. Flexion contractures greater than 10° after TKR and at least 4 to 8 weeks of conventional. physical therapy.	Heterotopic ossification, prosthetic malalignment, oversized components, or other motion-limiting abnormalities of the bone or prosthesis.	29 primary TKA, 18 revision TKA.	Custom-moulded knee device.		Knee ROM extension, knee society scores (KSS)	Knee extension improved from −22° to −1.4° KSS improved from 50 to 92 points
Papotto, 2012 [16] USA	RCT 8 weeks n = 20	Postoperative arthrofibrosis with failed traditional outpatient physical therapy, resulting in knee ROM of 90° or less in the first six postoperative week.	Sensory deficits (safety), ipsilateral hip arthroplasty.		High intensity stretching device.	Low intensity stretching brace.	Knee ROM flexion, % achieving 110° flexion, WOMAC scores.	Greater knee flexion in the IG (HIS) 111.5 ° (SD 6.7) versus 101.9° (SD 6.2) in the CG p = 0.001 91% of the IG achieved >110° knee flexion versus 22% of the CG Greater gains in WOMAC scores IG change = 25.6 points versus CG 12.4 points (p = 0.48).
Rauzi, 2022 [31] USA	Prospective Feasibility Cohort with retrospective cohort comparison	Unilateral primary TKR for OA with stiffness in first 6-weeks (flexion <100°)	Pre-op ROM less than 15–110; intra-operative ROM <0–120, heterotrophic ossification on X-ray, mal-aligned	All surgeries conducted by the same surgeon, all implants were cruciate retaining, and	Multimodal physical therapy ×twice weekly for 4 weeks. Manual therapy, therapeutic exercise and JAS static progressive splinting.	Retrospective comparator Standard protocol MUA followed by physical therapy	Knee ROM passive flexion and extension.	Greater knee flexion in the IG: 124.4° versus 111.6° in the CG (MUA group) Knee extension

(Continued)

Table 2. (Continued)

Author, year of publication and study location	Study design, duration, sample (n)	Eligibility criteria	Exclusion	Details of knee surgery undertaken	Intervention group (IG)	Comparator group (CG)	Outcomes reported	Primary findings
	4 weeks n = 41		components, joint infection, CRPS.	the patella was resurfaced in all cases.		× 2 weekly for 8 weeks.		was similar in both groups
Van Duren, 2024 [34] UK	Retrospective cohort with comparison 6 years n = 126	All patients who underwent first time MUA for a stiff primary TKA.	Patients undergoing revision total knee replacement (TKR) or those with any neuromuscular conditions affecting their mobility.	Not provided	Inpatient MUA + physiotherapy + CPM	Day Case MUA + Physiotherapy	Knee ROM, extension, flexion and total ROM.	Post-MUA knee flexion was 112° (SD 12) in the IG and 102° (SD 16.3) in the CG. Knee flexion at final FU was 97.7 (SD 15.5) for the IG and 93.1 (SD 19.6) for the CG. Both groups lost movement gained at MUA with CPM use providing no additional benefit.
Witvrouw, 2013 [15] Belgium	RCT 6 weeks n = 56	Active flex < 90° and or flexion contracture that negatively impacted function as reported by the patient.	Patients were examined both clinically and radiographically to exclude surgical errors or other potential factors contributing to the stiffness. Patients with coronal and sagittal component mispositioning, overstuffing of the patellofemoral compartment, patellar mal-tracking and mediolateral flexion space tightness were excluded.	Not provided.	Low load stretch device/ computer-controlled motion machine.	MUA.	Knee ROM, WOMAC	No significant difference in overall gains in ROMs between the IG, increase = 34.6° (SD 17) and the CG = 23.3° (SD 21). WOMAC scores also improved in both groups with no significant difference between them.

CG: comparator; CPM: continuous passive motion; IG: intervention group; JAS: joint active systems; KSS: knee society score; LEFS: Lower Extremity Functional Scale; MUA: manipulation under anaesthetic; OA: osteoarthritis; OKS: Oxford knee score; ROM: range of movement; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; KOOS: knee injury and osteoarthritis outcome score; SD: standard deviation; STAK: self-treatment-assisted knee tool; TKR: total knee replacement.

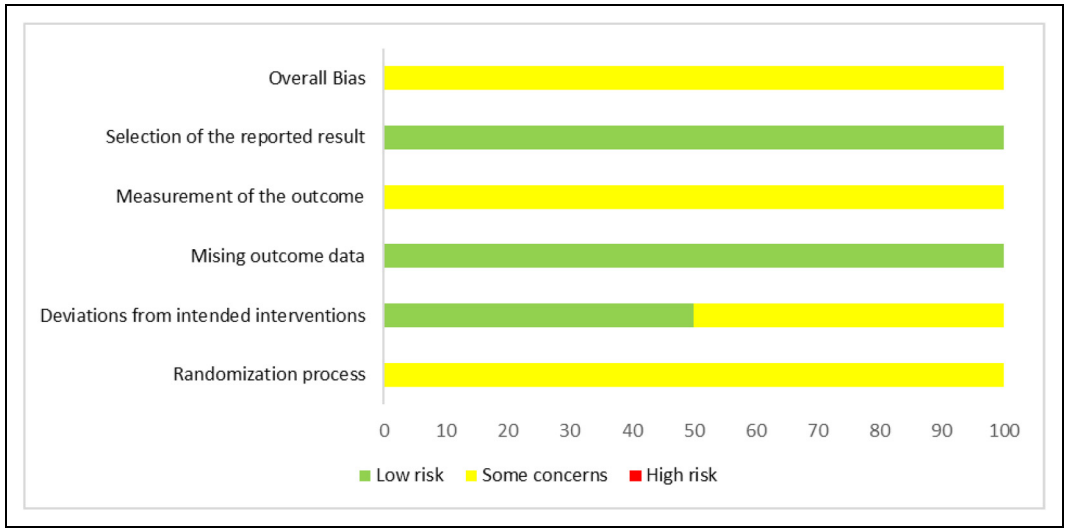

Figure 2. Risk of bias graph for randomised controlled trials.

Exercise

Seven studies incorporated exercise interventions.[15,31,36,38–41] There was a lack of detail regarding the specific procedures, including the frequency, duration, and intensity of exercises and/or any tailoring to individuals. Exercises predominantly focused on lower limb active-assisted range of motion exercises; flexibility exercises weight-bearing exercises, and task-specific activities such as sit-to-stand and step-ups. None of the interventions used exercise in isolation. Rather, they were combined with various adjunctive therapies or devices.

Manual therapy techniques

The interventions examined in this review encompassed three distinct manual therapy techniques. De Silva et al. 2018 employed a single three-minute session of myofascial release therapy, administered by a physical therapist, targeting various soft tissues surrounding the knee joint.[32] The use of Astym® soft tissue therapy was featured in three studies.[29,33,39] Astym® therapy involves using a handheld device designed for soft tissue manipulation and mobilisation, typically administered by a trained physical therapist. Two studies used manual therapy techniques focused on joint mobilisations.[31,40] For Dailey et al.,[40] participants received therapy once a week for a total of nine weeks, whereas for Rauzi et al.,[31] participants underwent therapy twice a week for a four-week duration, amounting to a total of eight sessions.

Use of mechanical devices and splinting

Eleven studies employed a mechanical device/splinting treatment component, including a Continuous Passive Motion device[34]; the Self Treatment Assisted Knee Tool©[41]; Joint Active Systems© Knee Device[28,31,35]; Customized Knee Device[30,39]; Ongoing Care Solutions © Sports Brace[29]; Dynasplint©[36]; End Range of Motion Improvement © hydraulic Knee Flexionater[16]; Low Load Stretch Device with Computer-Controlled Motion Therapy[15]; and a custom Orthosis-Based Stretching Device.[37] Each employed a unique mechanism to apply force across the knee joint, aiming to facilitate flexion and extension moment forces. Typically, devices were used for 30–60 min per day across two or three sessions, but splints were used for longer periods either overnight[36] or throughout the day.[39]

Other adjuncts

Three studies included in this review included Neuromuscular Electrical Stimulation as an adjunct to treatment.[13,14,29,30,32,38] One randomised controlled trial provided written information to the

Table 3. Risk of bias assessment for cohort studies using the Newcastle–Ottawa scale.

	Selection			Comparability		Outcome			Total
Study	Representativeness	Selection exposed cohort	Ascertainment	Result not present at study start	Comparability for confounders	Assessment of outcome	Follow-up duration	Adequacy of follow-up	
Bonutti, 2020[28]	*		*			*	*	*	5 – fair
Chughtai, 2016[33]	*	*	*		*	*	*		6 – good
Chughtai, 2016[29]			*	NA	NA		*		2 – poor
Silva, 2018[32]	*		*	NA	NA	*		*	4 – fair
McGrath, 2009[30]	*		*	NA	NA		*	*	4 – fair
Rauzi, 2022[31]	*	*	*				*	*	5 – poor
Van Duren, 2024[34]	*	*	*	NA			*	*	5 – poor

Zero stars indicate that the item is not registered in the article; good quality: 3 or 4 stars in the selection domain AND 1 or 2 stars in the comparability domain AND 2 or 3 stars in the outcome/exposure domain; fair quality: 2 stars in the selection domain AND 1 or 2 stars in the comparability domain AND 2 or 3 stars in the outcome/exposure domain; poor quality: 0 or 1 star in the selection domain OR 0 stars in the comparability domain OR 0 or 1 stars in the outcome/exposure domain.

Table 4. Risk of bias assessment for case studies using the Joanna Briggs Institute Critical appraisal checklist for case reports.

	Demographic described	History	Current clinical condition	Diagnostic tests appropriate	Treatment clearly described	Post-intervention condition	Adverse events described	Takeaway lessons
Behrns 2019 [38]	Y	Y	Y	N	N	Y	Y	Y
Bhave 2016 [39]	N	Y	Y	N	Y	Y	N	Y
Dailey 2018 [40]	Y	Y	Y	N	Y	Y	N	Y
Finger 2008 [36]	Y	Y	Y	N	Y	Y	Y	Y
Jansen 1996 [35]	Y	Y	Y	Y	Y	Y	Y	Y
Karam 2011 [37]	Y	Y	Y	N	Y	Y	Y	Y

Y: Yes; N: No.

Table 5. Strength of evidence summary.

Summary of results		Grading of recommendations assessment, development, and evaluation				
Outcome	Number of participants (studies)	Study design/ risk of bias	Inconsistency	Indirectness	Imprecision	Quality
Knee range of movement	344 (15)	Limitations[a,b,c]	Inconsistency[d,e]	Indirectness[f]	Imprecision[g]	⊕OOO Very Low
Function	181 (5)	Limitations[a,b,c]	Inconsistency[d,e]	Indirectness[f]	Imprecision[g]	⊕OOO Very Low
Manipulation under anaesthetic	145 (3)	Limitations[c]	Inconsistency[d,e]	Indirectness[f]	Imprecision[g]	⊕OOO Very Low

[a]Randomised controlled trial downgraded for the lack of allocation concealment, lack of blinding, and deviations from intended intervention.
[b]Observational studies automatically downgraded without special strengths.
[c]Non-randomised studies and case studies automatically downgraded to very low.
[d]Large heterogeneity.
[e]<400 participants.
[f]Wide variation in interventions.
[g]Small sample sizes.

participants, which included both textual and visual descriptions, specifically about the two available stretching devices.[16]

Intervention effectiveness

Range of movement

All of the included studies measured the range of movement of the knee. Seven of the studies reported the use of a goniometer as the method of measurement,[15,16,28,30,31,35,41] and one used photogrammetry using a digital camera,[32] with the remainder not documenting the method of measurement.

The randomised controlled trial by Papotto et al.[16] showed that a high-intensity stretching device produced significantly greater improvement in movement at a mean of eight weeks follow-up, achieving a mean change of 29.9° compared with 17.0° achieved with a low-intensity stretching brace, $p = 0.001$. Witvrouw et al.'s[15] 2013 RCT demonstrated significantly increased total range for patients receiving the intervention (a low-load stretch device with computer-controlled motion therapy) and the control intervention (manipulation under anaesthetic) with no significant between-group difference at six-week follow-up. Improvements in knee range for the low-load stretch device group were 34.6° (SD, 17.02) for the active movement and 35.4° (SD, 17.41) for the passive movement. The control group gained 23.3° (SD, 19.89) in active and 25.5° (SD, 21.12) in passive movement.

The non-randomised control trial of Aspinall et al.[41] showed greater improvement in total knee range following use of the Self Treatment Assisted Knee tool with self-directed stretching plus standard physiotherapy, with a mean improvement of 30° compared to eight degrees achieved with standard physiotherapy ($p < 0.0005$) at eight-week follow-up.

Three of the cohort studies included in this review had comparator groups. Chughtai et al.[33] did not report mean range but dichotomised results into patients achieving an optimal range of movement (defined as 110° for flexion and five degrees for extension) or not. They reported that all participants achieved an optimal range after undergoing a multimodal physical therapy protocol, compared with half of those receiving standard care after six months ($p = 0.005$).

Rauzi et al.[31] conducted a feasibility study also assessing a multimodal physical therapy programme. Though not powered to detect a significant difference between groups, they reported that knee range of movement was similar in the treatment group at a four-week follow-up (110° ± 14) compared to a retrospective cohort who had undergone manipulation under anaesthetic (109° ± 11). Additionally, seven out of the ten patients in the multimodal physical therapy program achieved functional range (≥110°) and avoided manipulation under anaesthetic. Van Duren et al.[34] compared patients who had undergone manipulation plus the use of continuous passive motion (carried out as an inpatient), to those who received manipulation only (as a day case). Both groups improved following the procedure, but the additional use of continuous passive motion for inpatients did not provide any additional benefits at the final follow-up.

Four cohort studies were without comparisons, all reporting improved knee movement following their experimental intervention. Bonutti et al.[28] demonstrated a median improvement of 25° in a cohort of 25 after a median duration of seven weeks of the Joint Active Systems© Knee Device. Chughtai *et al*.[29] (n = 23) demonstrated significant improvements in mean flexion deficit from 70° to 105° ($p < 0.001$) after a mean duration of Astym® therapy for two months. The total active range was significantly higher post-intervention, improving from a mean of 47° to 94° ($p < 0.001$) for participants with flexion deficit. For participants with a flexion contracture, the total range of active movement was also significantly higher post-intervention, improving from a mean of 56° to 101° ($p < 0.001$). Silva[32] demonstrated in a cohort of 33 that myofascial soft tissue release therapy improved range measured by photogrammetry using a digital camera by five degrees immediately post-treatment, corresponding to an 11.9% improvement ($p = 0.01$). McGrath et al.'s[30] cohort of 47 participants did not report pre- and post-movement but concluded that 40 of 47 patients showed improvement in flexion contractures ($p < 0.001$) with a custom-moulded knee device, after a mean duration of treatment of nine weeks.

The six case studies included in this review also reported improvements in knee movement. Behrns et al.'s[38] 3-stage rehabilitation programme was provided to one participant over 10 weeks after receiving manipulation under anaesthetic. At discharge, the participant's active flexion improved from 82° to 134° and extension improved from −10 ° to zero extension . Bhave et al.[39] reported that the participant's active flexion improved from 100° to 110° and active extension from −30° to −5°, after nine weeks of Astym ©therapy. Dailey et al.[40] reported on a focused physical therapy programme with eight sessions delivered prior to manipulation under anaesthetic and nine sessions after. Active knee flexion improved from 45° to 90° on discharge and passive from 48° to 116°. The participants in Finger et al.'s[36] study received dynamic splinting combined with physical therapy for 12 weeks over 28 sessions, with extension improving from 20° lacking full extension to full extension. Jansen et al.'s[35] participants were treated with the Joint Active Systems© Knee Device over 29 days and improved total active range by 17°. Finally, the two participants in the study of Karam et al.[37] were treated with a hinged cast brace for two weeks. The male participant improved their flexion range from 90° to 110° and extension range from 15° to three degrees after two months. The female participant improved their flexion range from 110° to 115° and extension range from 15° to three degrees.

Secondary outcomes

Function

Several patient-reported measures of function were reported across five studies, including the Western Ontario and McMaster Universities Osteoarthritis Index[42] in three studies[15,16,41]; the Oxford Knee Score[43] was also included in the Aspinall et al. study[41]; and the Knee Society Score[44] in two studies.[29,30] All patients receiving the investigated intervention in these studies demonstrated significant improvement in function. In the randomised controlled trial by Papotto et al.,[16] patients

demonstrated greater gains in function with the high-intensity stretching device compared to the low-intensity brace (change score equals 25.6 points versus 12.4; $p < 0.05$). Witvrouw et al.[15] reported no differences in function when comparing a low-load stretching device and manipulation under anaesthetic. Aspinall et al.[41] reported a change score of 19 points for the Self Treatment Assisted Knee Tool intervention compared to three points following usual physiotherapy in a non-randomised comparison.

Manipulation under anaesthetic and revision surgery

Chughtai et al.[33] reported zero incidence in the innovative multimodal physical therapy group compared to 20% in the usual care group at six months ($p = 0.025$). Rauzi et al.[31] reported three patients who underwent manipulation after failing to progress within four weeks of the multimodal physiotherapy programme. McGrath et al.[30] reported two patients who underwent further manipulation and additional surgery following six weeks of a customised knee device in conjunction with a standardised physical therapy regimen. Van Duren et al.[34] reported high rates of repeat manipulation for both groups; 25.3% for manipulation plus continuous passive motion versus 41% for the manipulation-only group. The length of the follow-up period was not reported, but the analysis spanned six years. This was the only study to report on revision surgery and was similar for both groups at around 16% over the same period.

Pain

Change in pain was reported in two case studies where joint mobilisation techniques completely resolved pain[40] and reduced from 10 to 2 on a numeric rating scale following Astym therapy.[39]

Global rating of change

A global rating of change score of seven was also reported following Astym therapy.[39]

Adherence

Two studies reported adherence using a participant-completed logbook and satisfaction/acceptability with the overall treatment approach using a seven-point Likert scale.[31,41]

Adverse events

Just one study reported some bruising due to tight strapping of a splint.[31] No other adverse events were reported.

Discussion

This systematic review aimed to explore the effectiveness of non-surgical interventions to improve knee range of movement in people with arthrofibrosis/stiffness following knee replacement. From the 16 studies identified, there was evidence to support interventions including exercise, manual therapy, and mechanical devices/splinting, to improve range of movement and function in patients with stiffness following knee replacement. However, the quality of the evidence was low. Several studies demonstrated gains in knee flexion >110° sufficient for functional activities in daily life, which would likely avoid the need for manipulation under anaesthetic or other more invasive interventions.[45] These included a randomised controlled trial of a high versus low-intensity stretching device where 91% of the high-intensity group achieved gains >110°;[16] a feasibility trial of a multi-modal physiotherapy programme where the mean increase in flexion was 124° compared to manipulation;[31] and a comparative cohort study of a physiotherapy programme compared to standard physiotherapy where mean flexion increased to 116° and 106°, respectively.

The included studies revealed significant heterogeneity in the interventions used, study design and follow-up, presenting challenges in drawing concrete conclusions regarding their efficacy. Seven of the included studies incorporated exercise interventions; however, a common limitation was the inadequate description of exercise protocols. Key details, including the specific procedures, frequency, duration, and exercise intensity, were often missing. Notably, just one included study by Rauzi et al.[31] provided full comprehensive details of the intervention.

Three distinct manual therapy techniques were observed in the reviewed studies. These techniques included myofascial release therapy, Astym® soft tissue therapy, and joint mobilisations. Although trained professionals administered these techniques and showed promise in improving range of knee movement, the limited number of studies and their high risk of bias in trial methodology make it challenging to draw definitive conclusions.

A wide array of mechanical devices and splinting methods were used across the included studies. The diversity in these approaches underscores the high heterogeneity in interventions, making it difficult to determine which device or method is most effective. Moreover, the lack of information about prescribed exercises alongside these mechanical devices limits our understanding of the comprehensive treatment approach. Significantly, none of the studies offered details on the cost of the interventions, leading to a lack of confidence in treatment recommendations, especially within the context of healthcare services with resource constraints.

All 16 studies assessed knee range of movement as the primary outcome measure; most studies focused on knee flexion, but three were primarily concerned with extension deficits.[30,35,36] Varying methods were used to assess range of movement including goniometers and photogrammetry using digital cameras, but several failed to specify how it was assessed. While the primary emphasis on range of movement is justified, the absence of other patient-relevant outcomes is notable. Only five studies reported changes in function over time and four reported on rates of manipulation under anaesthetic; all reported favourable results but there was a lack of longer-term follow-up. The Outcome Measures in Rheumatology working group has defined a core outcome set for hip/knee joint replacement trials, including pain, function, patient satisfaction, revision, adverse events, and death.[46] To ensure the comprehensive evaluation of interventions and inform clinical decision-making, future studies should aim to adopt the core domains and incorporate extended follow-up periods. This approach is important for capturing rates for manipulation under anaesthetic and revision surgeries.

There are several limitations in the included studies including small sample sizes, lack of control groups and variations in follow-up periods, which can affect the generalisability and strength of conclusions that can be drawn. Strengths of the review include the publication of the protocol *a priori*, and the completion of screening, selection, quality appraisal and data extraction in duplicate. We did not restrict the search by type of intervention to retrieve as many relevant studies as possible. Additionally, the search was updated at the time of write-up to ensure more recent studies were not missed. However, some studies may have been missed from the broader multidisciplinary databases such as Web of Science and Scopus and we did not search the grey literature.

The evidence for the efficacy of non-surgical interventions to improve movement, function and reduce the need for manipulation under anaesthetic or revision surgery in patients with stiffness after knee replacement is of low quality. However, they signal potential for an optimal non-surgical intervention to be developed, clearly described and tested in a future randomised controlled trial. Few studies met the requirements for the core outcome set for knee replacement research with just three studies reporting progression to manipulation under anaesthetic and revision surgery. Longer follow-up using core and patient-relevant outcomes including an economic analysis is required to determine overall effectiveness.

Clinical messages

- Non-surgical interventions may improve knee range of movement, function and reduce the need for future surgeries following knee replacement, but the quality of the evidence is very low.
- Heterogeneity in interventions and limited reporting on function and adverse events hinder conclusive recommendations.
- Future research should prioritise standardised reporting, larger sample sizes, and adherence to core outcome sets to inform

optimal non-surgical approaches for stiffness post-knee replacement.

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Supplemental material

Supplemental material for this article is available online.

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