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Review

Key components of rehabilitation programmes for adults with complex fractures following traumatic injury: A scoping review

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ABSTRACT

Introduction: Complex fractures are severe injuries that cause considerable disability, particularly in the working population. Effective rehabilitation is essential to achieve good outcomes, however, it is unclear what the best rehabilitation strategy is for adults with complex fractures, after their discharge from hospital. The aim of this scoping review was to identify and map the breadth of evidence available on this topic.

Methods: A systematic search was completed on 24th July 2023 using a combination of subject and specialist databases. In addition, a secondary search assessed unpublished literature from trial registries. A citation search was completed on the selected studies. The template for intervention description and replication (TIDieR) checklist was used to extract consistent data on the interventions reported in the studies. The Joanna Briggs Institute methodology for scoping reviews was followed.

Results: 19,253 studies were identified from the search strategy of which 25 studies met the eligibility criteria. Most interventions were exercise-based and delivered by physiotherapists. Some studies compared manual therapy treatments to other forms of physiotherapy or a placebo, whilst others investigated psychosocial interventions, such as cognitive behavioural therapy, in comparison to usual care. Two studies took a multidisciplinary team approach, incorporating components such as exercise, functional activities and self-management strategies.

Discussion: The studies included were heterogenous in terms of population (fracture type, location and complexity), intervention content and therapeutic aims. However, commonalities were found with most interventions or comparators including range of movement, strengthening and task specific exercises; functional tasks; gait and balance training; and advice on return to activities as components. Value was attributed to components such as, a coordinated team approach, person-centred rehabilitation, supervised exercise and psychosocial support.

Conclusion: There is a broad and varied approach to the rehabilitation of complex fractures. The studies differed in population and approach, with a wide range of injuries, interventions and modes of delivery reported. Fidelity was poorly described, with only a third of studies reporting adherence or acceptability. There was inconclusive evidence to inform clinical practice and further research is advised. Qualitative, expert consensus, and coproduction approaches are recommended methods to develop complex interventions and best practice guidance.

Introduction

Complex fractures are life-altering injuries associated with significant morbidity, which places a large burden on health and social care resources [1,2]. The impact is felt by the individual, their family and friends, and wider society. Return to work rate is low, with only 50–64 % returning to their previous employment by 2-years post injury [3,4]. Inability to work often results in financial hardship and social isolation

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[5].

Complex fractures are injuries that involve severe breaks to a bone or multiple bones and require specialist treatment. The definition used by the James Lind Alliance Priority Setting Partnership for complex fractures was also used in this review [6]. This definition encompasses fractures to the pelvis, acetabulum, upper and lower extremities, where the bones are broken into multiple pieces (comminuted or intra articular), open fractures with significant soft tissue damage, and/or multiple fractures at the same time to one or more limbs. It does not include fractures to other parts of the body such as head, face, spine or ribs.

In the UK, most patients with complex fractures are treated acutely in a Major Trauma Centre or Trauma Unit, where all the required specialist teams and facilities are available. However, the question for this review focuses on the next stages of their recovery and specifically rehabilitation after hospital discharge. This is often referred to as outpatient or community rehabilitation and can take place in a variety of settings outside of acute hospital wards, for example, outpatient departments, community hospitals, leisure centres, or an individual's home or workplace [7].

The importance of rehabilitation in achieving good outcomes and preventing complications is well recognised [8,9]. Rehabilitation is defined as a set of interventions designed to optimise function and reduce disability in individuals with health conditions [10]. These interventions are complex and multifactorial but can be broken down into individual components. Each component is a planned rehabilitation activity and within the context of healthcare is prescribed and/or delivered by a trained healthcare professional. These activities can be physical, psychological, and/or socioenvironmental [11,12].

At present, it is unclear what the best rehabilitation strategy is for adults with complex fractures, after their discharge from hospital. The James Lind Alliance priority setting partnership for complex fractures highlighted the importance of this research question to stakeholders [6]. The aim of this scoping review was to identify and map the breadth of evidence available on this topic. Ethical approval was obtained from (Coventry University) Ethics Committee (P161717).

Research question

What are the key components of interventions used to rehabilitate adults with complex fractures following traumatic injury after their discharge from hospital?

Methods

This scoping review was conducted by the lead author (LS) in accordance with the Joanna Briggs Institute methodology for scoping reviews [13]. This comprehensive guidance ensures clarity and rigour during the review process [14]. The Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping reviews (PRISMA-ScR) guidance [15] was used to ensure accurate and objective reporting. The protocol was registered prospectively on The International Prospective Register of Systematic Reviews (https://www.crd.york.ac.uk/prospero/ - CRD42023332583).

Search strategy

A comprehensive search was completed on 24th July 2023 using a combination of subject and specialist databases. The electronic databases MEDLINE, Embase, Scopus, CINAHL Ultimate, AMED, PsycInfo, PEDro, and OTseeker were searched separately using EBSCOhost and Ovid as the main platforms.

The databases were searched from 1st January 2000 to ensure the studies selected reflected contemporary therapeutic and rehabilitation practices. Trauma care changed significantly in England in the mid-2000s with the reorganisation of National Health Service (NHS) services and introduction of a National Major Trauma System [16,17]. This led to improvements in the care process and patient outcomes following traumatic injury [18]. 'Human' was the only other limit applied.

Key words and Medical Subject Heading terms for complex fractures and rehabilitation were used relevant to each database. Rehabilitation is a broad term, which covers topics unrelated to this review such as drug or alcohol addiction. To ensure the search was focused, the key words were derived from a recent Cochrane review [19]. Searches were imported and managed in EndNote X9 (Clarivate, Philadelphia, PA, USA) [20] and duplicate citations removed. The references were imported from EndNote to Covidence (Veritas Health Innovation, Melbourne, Australia.) [21] and further duplicate citations identified and removed. Covidence is a web-based collaboration software platform and was used to facilitate and report the screening process. The search strategies for each database can be found in Supplementary file 1.

Study selection

The titles and abstracts were screened independently by two reviewers (LS and AH) using the eligibility criteria shown in Fig. 1. Full text screening was completed if it was unclear whether the study should be included. The articles not available in English were translated using DeepL Translator software (DeepL SE, Cologne, Germany) [22]. The titles and abstracts were copied and pasted into the software for review. None of these articles met the inclusion criteria.

A secondary search assessed unpublished literature from the ClinicalTrials.gov and International Standard Randomised Controlled Trial Number (ISRCTN) trial registries. A reference list and Google Scholar forward citation search were also completed on all the selected studies to reduce the risk of missing preliminary evidence [23]. Any resources relating to the rehabilitation interventions were sourced and included in the review. This grey literature included protocol papers, supplementary information and contacting the authors.

Exclusion criteria

Children under 16 years old were excluded. Complex fractures are rare in this population as juvenile bone is more porous and flexible than adult bone [24]. An $\geq$16 years age limit is in keeping with national and international studies completed in this field [25,26].

Some adults sustain complex fractures following a low energy mechanism of injury or with no history of trauma identified. These are referred to as fragility and/or pathological fractures due to underlying bone disease such as osteoporosis, bone cancer, or osteogenesis imperfecta. Alternatively, complex fractures can be caused as a complication of surgery (intra-operative) or occur around previous bone fixation (periprosthetic). The recovery and rehabilitation pathway for people with these types of complex fractures is significantly different from those who are the primary focus of this study. Therefore, any studies relating to fragility, pathological, intraoperative or periprosthetic fractures were excluded.

Research undertaken in a critical care unit or acute ward setting were excluded as they did not fit the setting criteria for outpatient or community rehabilitation.

Data extraction

Two reviewers (LS and AH) independently extracted data using a template based on the characteristics of included studies table used in Cochrane reviews [27]. This dual extraction method is recommended to reduce errors and improve the quality of data collection [28]. Due to time and resource constraints the second reviewer (AH) completed data extraction on 50 % of the selected studies.

The Template for Intervention Description and Replication (TIDieR) checklist [29] was used by both reviewers (LS and AH) to extract consistent and detailed information on each of the study's intervention components and mode of delivery. If a study had supplementary

Eligibility criteria
1) Primary empirical research 2) Human participants 3) Adults ≥16 years 4) Complex fractures: fracture of the pelvis, acetabulum, upper or lower extremities; fractures to joints/bone broken into multiple pieces (comminuted or intra articular); open fractures with skin loss or significant soft tissue damage; multiple fractures in one or more limbs at the same time. 5) Traumatic mechanism of injury: a physical injury which occurs suddenly by an external force such as a fall, road traffic collision, work or recreational accidents, or violent assault. 6) Non acute setting: any outpatient, community and/or residential rehabilitation setting including the person's home. 7) Rehabilitation intervention-based study: any planned rehabilitation activity undertaken within an intervention to improve the person's physical, psychological and/or socioenvironmental recovery. 8) Full text or supplementary information available on intervention
Exclusion: fragility, pathological, intra-operative and periprosthetic fractures.

Fig. 1. Eligibility criteria for this scoping review.

information available these resources were grouped together and extracted as a single study. Data was also extracted from the control intervention if sufficient data was available. TIDieR is a validated checklist developed to improve how interventions are objectively described and reported [30].

Data synthesis

The extracted data was collated, summarised and reported by the lead author (LS) and checked by the second reviewer (AH). The TIDieR checklist was used to organise the results, and the findings presented in a tabular format with accompanying narrative [31]. Each intervention and their comparators were comprised of multiple components. These were categorised using an adaptation of the validated Stroke Physiotherapy Intervention Recording Tool, which has been designed to define and describe the content of rehabilitation interventions [32].

Results

Characteristics of included studies

The results of the search strategy are shown in the PRISMA diagram (Fig. 2). It illustrates that once duplicates were removed, 19,253 references were screened for eligibility. Of these 19,180 were excluded based on title and abstract information. A total of 73 full text articles (58 studies) were retrieved and screened by both reviewers. Some studies had several publications related to a single study. The eligibility criteria were met in 25 studies, with 33 studies excluded due to the wrong population, intervention or study design. The reviewers (LS and AH) agreed on all the studies to be included, with a kappa value of 0.92. Any value above 0.90 is considered almost perfect agreement, meaning the data is reliable [33].

The studies were predominantly randomised controlled trials (RCT) ($n = 22$) with a range in sample sizes from 30 to 325 participants. The RCTs included three pilot studies [34-36] and two studies where the protocol had been published giving details of the interventions, but the main studies were still ongoing [37,38]. This did not impact the results as effectiveness of the interventions was not a criterion for this review. In addition, there was one non-randomised controlled trial (NRCT) [39] and two observational cohort studies [40,41]. A summary of the characteristics of included studies are shown in Table 1.

Review findings

The majority of the interventions reported were exercise-based ($n = 15$) and delivered by physiotherapists ($n = 19$). Some studies focused on a single treatment or series of treatments related to a specific manual therapy technique, stretch or exercise prescription, whilst others focused on adjuncts to therapy such as the antigravity treadmill. A few larger studies explored psychosocial interventions and/or a multidisciplinary team (MDT) approach to rehabilitation, but with varied intensity and mode of delivery including virtual and residential. Nearly all the studies ($n = 21$) delivered their intervention using in-person, individual therapy sessions. The description of the interventions based on the TIDieR checklist are presented in Table 2. Full details on the materials used; intervention frequency, duration and dose; and acceptability of the interventions to service users can be found in Supplementary file 2.

All the studies included complex fractures. However, it was difficult

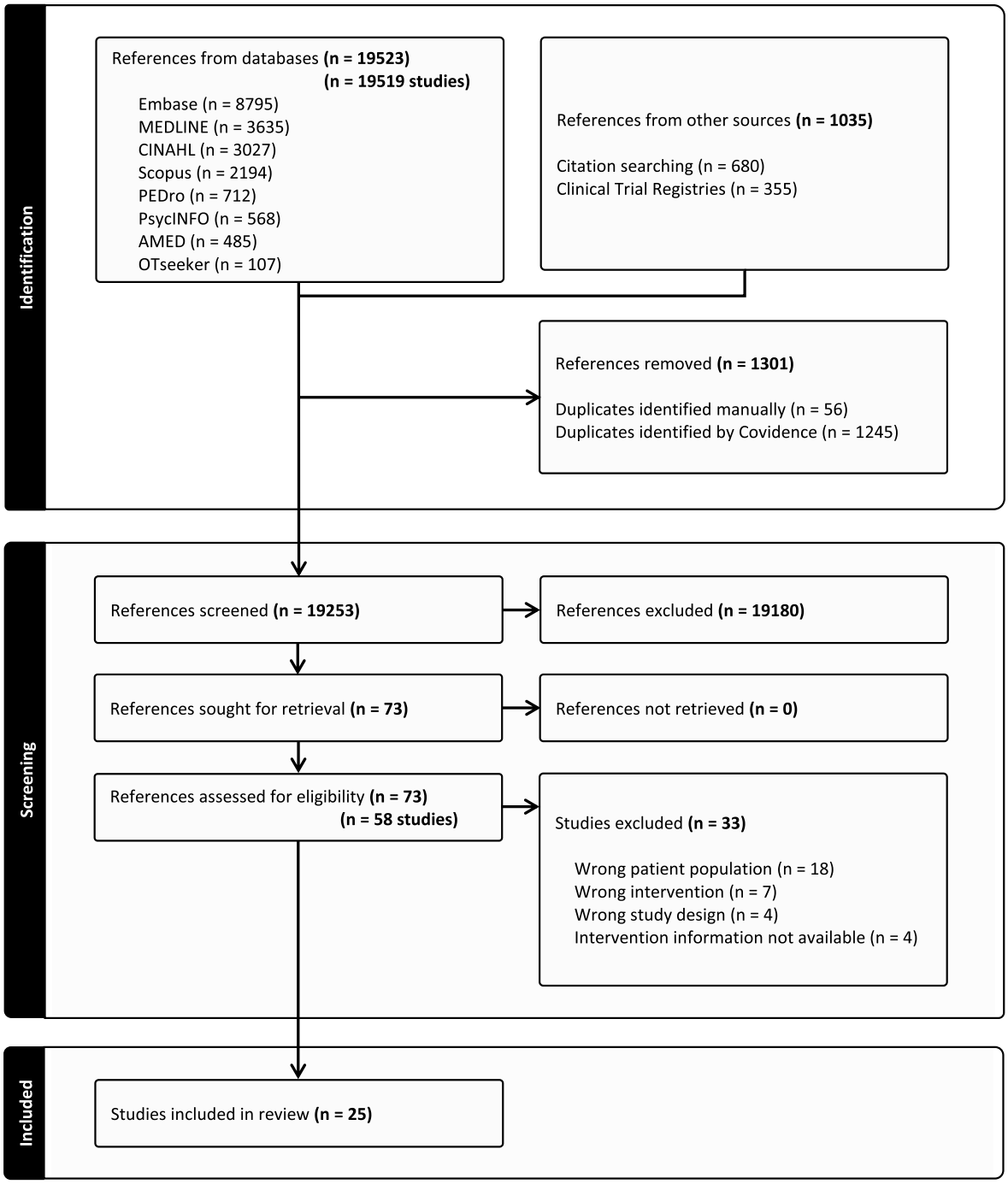

Fig. 2. PRISMA diagram showing the search strategy.

to separate non-complex from complex fractures in some of the studies' where the population contained a variety of fracture types including proximal, shaft and condylar femur fractures; closed and open tibial plateau and patella fractures; unimalleolar, bimalleolar and trimalleolar ankle fractures; any elbow or knee fracture. Despite this heterogeneity in fracture type, location and complexity, commonalities were found across the studies, as shown in Table 3.

None of the manual therapy treatments including joint mobilisation [42-46], desensitisation [47], proprioceptive neuromuscular facilitation [48] and muscle energy technique [36] were shown to be significantly more effective than other forms of physiotherapy to improve range of movement and function of the injured limb.

Nearly all the interventions or comparators included range of movement and strengthening exercises. Task specific exercises tailored to the individual, were more effective in reducing disability, pain and improving quality of life than general exercises [39,49,50]. Several studies reported that supervised exercise had better outcomes and participant satisfaction than unsupervised exercise [41,42,44,48-50]. However, Moseley et al. [51,52] showed no benefit to supervised exercise over advice alone but with the limitation that their population was predominantly isolated and uncomplicated ankle fractures.

Several studies involving isolated lower limb or ankle fractures used therapy adjuncts to improve strength, proprioception and balance [38, 40,41,45,46,53-55]. Neither the visual feedback training [55] or the transcutaneous electrical acupoint simulation (TEAS) [46] intervention showed any significant improvement compared to usual care. The

Table 1
Summary of characteristics of included studies.

Reference	Study design	Sample size	Population characteristics	Intervention & Comparator	Follow-up & Outcome	Key Findings
Albin et al, 2019 [44]	RCT	**72**	27-58 years	Manual therapy – joint mobilisation techniques specific to fracture location.	7-10 days	Both groups already receiving exercise and gait training. Manual therapy may decrease resting muscle stiffness after ankle/ hindfoot surgical fixation.
United States of America (USA)		40 (intervention) 32 (sham therapy)	46 men, 26 women Civilian & military Ankle and hindfoot fractures Surgical fixation	Sham manual therapy - light soft tissue mobilisation and Grade I-II proximal tibiofibular joint mobilisations.	Primary outcome: Functional health status Secondary outcomes: Anxiety, swelling & range of movement (ROM) A short course of manual therapy (3 treatments) showed no benefit.	
Archer et al, 2022 [57]	RCT	**325**	18-60 years	CBPT-Trauma programme – patient orientated cognitive behavioural self-management approach.	6-months & 12-months	Aim to determine the efficacy of CBT based programme delivered by physiotherapists over the telephone.
USA		1:1 ratio to intervention or education group	Gender not reported Civilian & military Lower limb, pelvic or acetabular fractures Surgical fixation	Education programme – standard written information on post operative recovery.	Primary outcome: Functional health status Secondary outcomes: Physical performance, pain, return to work or activities, health service utilisation Study still in intervention phase – no reported outcomes.	
Birinci et al, 2019 [48]	RCT	**40**	32-51 years	Proprioceptive neuromuscular facilitation (PNF) stretching combined with structured exercise.	1-month	A structured exercise programme combined with PNF stretching provides a slightly greater overall improvement in posttraumatic elbow stiffness.
Turkey		20 per group	16 men, 24 women Elbow fractures Operative: 12 (PNF), 13 (SS) Non-operative: 8 (PNF), 7 (SS)	Static stretching (SS) combined with structured exercise.	Primary outcome: Upper limb function Secondary outcomes: ROM, pain, kinesiophobia, patient satisfaction, quality of life (QoL) Slight improvement in outcomes for PNF group.	
Bouman et al, 2017 [39]	NRCT	**132**	18-75 years	Fast Track multi-trauma rehabilitation service.	3, 6, 9 & 12-months	Both rehabilitation programmes were effective. A faster recovery in Fast Track group at 6-months but no difference at 12-months.
Netherlands		65 (intervention) 67 (conventional rehabilitation)	105 men, 27 women Complex multiple injuries on both lower limbs or combination of upper limb & lower limb or complex pelvic/ acetabular fractures Surgical fixation	Conventional trauma rehabilitation service.	Primary outcome: Functional health status Secondary outcomes: Anxiety & depression, QoL Both groups improved their functional status and quality of life.	
Browne et al, 2013 [34]	RCT (pilot)	**142**	21-52 years	Multidisciplinary assessment & treatment in an MDT clinic at 1-month & 3-months post injury.	6-months	Coordinated early MDT interventions show promise

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Table 1 (*continued*)

Reference	Study design	Sample size	Population characteristics	Intervention & Comparator	Follow-up & Outcome	Key Findings
						for reducing long-term disability.
Australia		69 (intervention) 73 (usual care)	106 men, 36 women Traumatic injury defined by mechanism – included complex fractures. Operative/ non-operative management not reported	Usual care – routine follow-up with surgeon, GP ± referral to therapy.	Primary outcome: Pain & psychological status Secondary outcomes: Function, physical performance, balance Highlighted significant need for specialist assistance with pain management, mobilising & psychological symptoms.	
Busse et al, 2022 [37]	RCT (protocol)	**n/a**	≥18 years	Cognitive behavioural therapy to optimise post-operative fracture recovery (COPE) – online CBT modules.	3, 6, 9 & 12-months	Aim is to promote a new model of care that supports psychological barriers after traumatic fracture repair.
Canada			Gender n/a Open or closed extremity fractures Surgical fixation	Usual care – not defined.	Primary outcome: Pain Secondary outcomes: Psychological status, functional health status, QoL, fracture complications Study still in intervention phase – no reported outcomes.	
Gillani et al, 2021 [42]	RCT	**60**	26-46 years	Supervised elbow exercises & elbow distraction with traction belt by clinician.	6-months	Both groups were effective in reducing pain and disability. Supervised exercise improved range of movement, mobility and function.
Pakistan		30 per group	43 men, 17 women Open or closed distal humerus fractures Surgical fixation	Unsupervised elbow exercises & self-distraction at home.	Primary outcome: Pain Secondary outcomes: Functional health status, ROM Outcomes were significantly better in supervised exercise group.	
Henkelmann et al, 2021 [45]	RCT	**73**	18-65 years	Antigravity treadmill therapy & cryotherapy instead of standard rehabilitation.	3 & 6-weeks	Patients who had undergone postoperative anti-gravity treadmill therapy had less symptoms and higher quality of life and a significantly better gait with lesser muscle atrophy than those on standard rehabilitation.
Germany		37 (intervention) 36 (standard rehabilitation)	34 men, 39 women Closed tibial plateau fractures or ankle fractures Surgical fixation	Standard rehabilitation – cryotherapy, passive movements & gait training with a physiotherapist.	12-months (Palke et al, 2022) Primary outcome: Functional health status Secondary outcomes: Pain, muscle atrophy QoL, return to sport Antigravity treadmill outcomes were comparable with standard rehabilitation.	
Hsu et al, 2017 [40]	Cohort	**87**	18-60 years	Custom fitted Intrepid Dynamic Exoskeletal Orthosis (IDEO)	12-months	Benefits for limb salvage patients but requires further

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Table 1 (*continued*)

Reference	Study design	Sample size	Population characteristics	Intervention & Comparator	Follow-up & Outcome	Key Findings
				brace and 'Return to Run' physiotherapy programme.		research in the civilian population.
USA			Gender not reported Military – active or retired ≥ 1 year post unilateral lower limb open fracture at or below the knee Surgical fixation Healed fracture and able to fully weight bear		Primary outcome: Physical performance & functional health status Secondary outcomes: Pain, psychological status, patient satisfaction, return to work, health service utilisation Positive benefits to the combined IDEO & physiotherapy programme as an alternative to limb amputation.	
Jansen et al, 2018 [53]	RCT	**50**	22-75 years	Physiotherapy with active controlled motion (ACM) device.	6 & 12-weeks	In people with unstable ankle fracture, the use of ACM is associated with improved clinical outcomes including quicker return to work.
Germany		25 per group	27 men, 22 women (1 not reported) Unstable ankle fractures Surgical fixation Partial weight bearing for 6-weeks	Physiotherapy alone – oedema management & range of movement exercises.	Primary outcome: ROM Secondary outcomes: Functional health status, return to work, pain, dynamic pedography Improved outcomes in the ACM group – mobility, range of movement & return to work.	
Keene et al, 2022 [35]	RCT (pilot)	**61**	53-74 years	Progressive exercise (PE) – home exercise and advice programme overseen by a physiotherapist.	6-months	It is feasible to do RCT. This will assess the clinical effectiveness of supervised rehabilitation versus self-directed rehabilitation for adults ≥50 years after ankle fracture.
United Kingdom		31 (intervention) 30 (advice only)	19 men, 42 women Ankles fractures Operative: 15 (PE), 12 (BPA) Non-operative: 13 (PE), 15 (BPA) Unknown: 6 Ankle immobilisation for ≥4 weeks	Best practice advice (BPA) – home exercise and advice programme initiated during a single physiotherapy session.	Primary outcome: Functional health status Secondary outcomes: Pain, falls, return to activities, mobility status, health service utilisation, ROM, muscle strength, balance Feasibility assessment for recruitment, completion of intervention sessions & follow-up rate.	
Kim et al, 2020 [54]	RCT	**34**	42-57 years	Antigravity treadmill training.	4-weeks	Both groups showed improvement in muscle strength, endurance, and activities after the intervention. Antigravity treadmill training offers a rehabilitation protocol for a stable and effective gait in patients with a femoral fracture.
South Korea		17 per group	26 men, 8 women	Conventional rehabilitation – range of movement & strengthening exercises.	Primary outcome:	

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Table 1 (*continued*)

Reference	Study design	Sample size	Population characteristics	Intervention & Comparator	Follow-up & Outcome	Key Findings
			Femur fractures Surgical fixation		Muscle strength Secondary outcome: Electromyography for neuromuscular activity during isometric contraction Significantly more muscle strength in hip and gluteal muscles with antigravity treadmill training.	
Lin et al, 2008 [43]	RCT	**94**	28-56 years	Manual therapy (MT) – large amplitude grade III anterior-posterior joint mobilisation of the talus + standard physiotherapy.	4, 12 & 24-weeks	Manual therapy did not improve outcomes in adults after ankle fracture.
Australia		47 per group	51 men, 43 women	Standard physiotherapy (SP) – exercise, gait re-training, oedema management & advice on return to activities.	Primary outcome:	
			Ankle fractures		Functional health status & QoL	
			Operative: 30 (MT), 26 (SP)		Secondary outcomes: Gait, ROM, return to work or activities, patient satisfaction, pain	
			Non-operative: 17 (MT), 21 (SP)		No difference between the two groups.	
Monticone et al, 2021 [49]	RCT	**70**	38-60 years	Supervised rehabilitation programme of task-orientated exercises based on the person's job activities, and occupational therapy.	12-weeks & 12-months	General physiotherapy should be progressively avoided in clinical practice, in favour of exercises which promote functional outcomes in order to guarantee earlier return to pre-fracture physical levels.
Italy		35 per group	29 men, 41 women	General physiotherapy – supervised mobility, strengthening & stretching exercises.	Primary outcome:	
			Unstable, displaced proximal humeral fractures Surgical fixation		Upper limb function Secondary outcomes: Pain, functional health status Task-orientated exercises and occupational therapy was superior to general physiotherapy in improving disability, pain and quality of life.	
Moseley et al, 2005 [52]	RCT	**150**	28-64 years	Exercise + long stretch (ELS)	3-months	No benefit to passive stretching over an exercise programme after ankle fracture.
Australia		51 (long stretch) 49 (short stretch)	71 men, 79 women Ankle fractures	Exercise + short stretch (ESS) Exercise only (EO) – ankle movement & strengthening, stepping, weight bearing & balance exercises.	Primary outcome: Functional health status & ROM	
		50 (exercise only)	Operative: 24 (ELS), 26 (ESS), 33 (EO)		Secondary outcomes: Pain, stiffness, return to work or activities, gait, mobility, patient satisfaction	
			Non-operative: 27 (ELS), 23 (ESS), 17 (EO)		No difference between the groups.	
Moseley et al, 2015 [51]	RCT	**214**	26-60 years	Supervised, individually tailored exercise programme with advice about self-management.	1, 3 & 6-months	A supervised exercise programme did not offer additional benefits compared with advice alone for adults with isolated and

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Table 1 (*continued*)

Reference	Study design	Sample size	Population characteristics	Intervention & Comparator	Follow-up & Outcome	Key Findings
						uncomplicated ankle fracture.
Australia		106 (intervention) 108 (advice only)	94 men, 120 women Ankle fractures Operative: 47 (Exercise), 51 (AO) Non-operative: 59 (Exercise), 57 (AO)	Advice only (AO) – single session of self-management advice about exercise & return to activity.	Primary outcome: Functional health status, QoL & economic evaluation Secondary outcomes: Pain, return to work or activities, ROM, gait, physical activity, QoL No difference between the groups.	
Nilsson et al, 2009 [50]	RCT	**105**	18-64 years	12-week training programme – exercises and functional activities.	6 & 12-months	The training programme showed superior results compared to usual care regarding subjectively scored function and muscle strength.
Sweden		50 (intervention) 55 (usual care)	43 men, 62 women Ankle fractures Surgical fixation	Usual care – advice post cast removal ± referral to local physiotherapy service dependent on surgeon.	Primary outcome: Functional health status Secondary outcomes: Gait, mobility, muscle strength, ROM Improved function & muscle strength with training programme.	
Reilly et al, 2021 [41]	Cohort	**15**	35-66 years	Virtual reality-based physiotherapy training programme with exercises, games & progress dashboard.	No follow-up	Virtual reality-based physiotherapy programmes may add value for patients and clinicians as a practical supplement or alternative to traditional physiotherapy.
Lebanon			9 men, 6 women Femur or tibia fractures Surgical fixation		Primary outcome: Acceptability of intervention Secondary outcomes: Feasibility & usability of intervention Virtual reality was acceptable, feasible & useable in the clinical setting.	
Shah & Shinde, 2013 [47]	RCT	**30**	20-64 years	Desensitisation techniques + conventional physiotherapy.	No follow-up	Combination of desensitisation and conventional physiotherapy was effective in decreasing pain and improving strength and range after upper limb fracture.
India		15 per group	11 men, 19 women Upper limb fractures Operative/ non-operative management not reported	Conventional physiotherapy only – heat, mobilisation, exercises.	Primary outcome: Pain Secondary outcomes: Upper limb function, ROM, muscle strength Desensitisation showed some improvement in elbow range & strength post treatment.	
Shende et al, 2022 [36]	RCT (pilot)	**20**	10-30 years	Muscle energy technique (MET) – post isometric relaxation.	No follow-up	MET could be beneficial in reducing pain and increasing range of movement in the elbow joint.
India		10 per group	Gender not reported Extra- and intra-articular humerus fractures Surgical fixation	Static stretching.	Primary outcome: Pain Secondary outcome:	

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Table 1 (*continued*)

Reference	Study design	Sample size	Population characteristics	Intervention & Comparator	Follow-up & Outcome	Key Findings
					Upper limb function Both groups showed improved range of movement post treatment.	
Stinner et al, 2022 [38]	RCT (protocol)	**n/a**	18-55 years	Antigravity treadmill training – 10-week programme from non to full weight bearing.	6-weeks, 3, 6 & 12-months	Aim is to develop future treatment protocols for periarticular fractures of the lower extremity, providing a safe approach to optimise rehabilitation.
USA			Gender n/a	Usual care – to remain non or touch weight bearing on crutches for at least 8-weeks.	Primary outcome:	
			Civilian & military Open or closed femur, tibial plateau or tibia fractures Surgical fixation		Functional health status Secondary outcomes: Return to work or activity, ROM, muscle strength, physical performance, gait, mobility, fracture healing & complications Study still in intervention phase – no reported outcomes.	
Vranceanu et al, 2015 [58]	RCT	**48**	33-70 years	Mind body skills intervention – relaxation strategies, cognitive & behavioural therapy, strategies to engage in activity.	No follow-up	Improvements in activity, disability, coping and mood in the intervention group. A larger trial using videoconferencing is recommended.
USA		28 (intervention)	18 men, 30 women	Usual care – follow-up visits to surgeons ± physiotherapy or occupational therapy.	Primary outcome:	
		20 (usual care)	Musculoskeletal trauma within the past 1-2 months Operative/ non-operative management not reported		Functional health status & pain Secondary outcomes: Kinesiophobia, anxiety & depression Feasible and acceptable intervention.	
Wu et al, 2022 [46]	RCT	**57**	28-53 years	Standard care + PNF training + Transcutaneous electrical acupoint stimulation (TEAS) intervention.	3 & 6-weeks	TEAS as an additional analgesic measure may sustain efficacy of PNF training for a longer period.
China		18 (PNF) 20 (PNF+ TEAS)	31 men, 23 women Closed tibial plateau fractures	Standard care + PNF training. Standard care – exercises, mobilisation techniques, gait training, resistance training.	Primary outcome: Postural stability & muscle strength	
		16 (standard care)	Operative/ non-operative management not reported		Secondary outcome: Pain The standard care + PNF training + TEAS intervention showed greater improvement in pain, strength and static & dynamic postural stability.	
Zdziarski-Horodyski et al, 2020 [59]	RCT	**112**	24-61 years	Integrative care – 10-step psychosocial self-empowerment support programme.	2, 6, 12 & 24-weeks	There is a need for further research to develop effective psychosocial approaches to caring for orthopaedic trauma patients.
USA		52 (intervention)	59 men, 53 women	Usual care – standard orthopaedic trauma care with surgeon, physiotherapy & occupational therapy.	Primary outcome:	
		60 (usual care)	Severe or multiple orthopaedic trauma Surgical fixation		Functional health status & grip strength Secondary outcomes:	

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Table 1 (*continued*)

Reference	Study design	Sample size	Population characteristics	Intervention & Comparator	Follow-up & Outcome	Key Findings
					Physical performance, ROM No difference between the groups.	
Zhang et al, 2022 [55]	RCT	**104**	35-57 years	Routine rehabilitation + visual feedback training (VFT).	4 & 8-weeks	Both groups showed an improvement in gait, balance and function. VFT could be a useful addition to rehabilitation.
China		52 per group	68 men, 36 women	Routine rehabilitation – exercises, gait training, resistance training.	Primary outcome:	
			Knee fractures Surgical fixation		Functional health status Secondary outcomes: Balance, mobility VFT may decrease postural sway and increase motor control in post-operative patients with knee fracture.	

Intrepid Dynamic Exoskeletal Orthosis (IDEO) combined with a 'return to run' rehabilitation programme showed positive benefits, but the authors recognised that this intervention needed to be tested in a civilian population [40]. Jansen et al. [53] used an active controlled motion device and demonstrated a slight improvement in clinical outcomes for unstable ankle fractures. The antigravity treadmill proved the most effective adjunct. It was found to significantly improve strength in the hip and gluteal muscles [54], gait pattern [45], and a higher quality of life at 12-months post injury compared to those who had received standard care [56].

Six studies focused on psychosocial interventions and/or an MDT approach to rehabilitation integrating physical and psychological components [34,37,39,57-59]. Their study populations had the highest complexity, and their interventions were the most intensive. There were similarities in the psychological components tested, in particular, self-management strategies to grade activity and optimise function [34, 37,57-59], cognitive behavioural therapy (CBT) [34,37,57], mindfulness and/or relaxation techniques [37,57-59], coping strategies and stress management [34,37,57-59]. Most interventions incorporated person-centred goal setting [34,35,39,50,59], advice on return to work or activities [34,43,50,51,57], and advice on exercise, sleep and healthy eating [37,39,59]. Virtual delivery was described as a facilitator, but with the option of telephone communication for people without the skills or access to internet enabled devices [37,57,58].

Discussion

The aim of this study was to identify the key components of interventions used to rehabilitate adults with complex fractures following traumatic injury, after their discharge from hospital. The review examined literature since the year 2000, with most studies (n = 18) published since 2017.

On the whole, the interventions were poorly defined when the TIDieR checklist was applied for data extraction. Details about the interventions were missing and fidelity was rarely reported. There was minimal stakeholder engagement described and only a third of studies included acceptability of the intervention to the service user as an outcome. However, this issue is not unique to this population. Poor reporting of therapy interventions is evident from the wider literature [60,61].

The main finding was a broad and varied approach to the rehabilitation of complex fractures. The studies included had a wide degree of heterogeneity with regards to populations studied (fracture type, location and complexity), interventions' content and therapeutic aims. However, commonalities were found across the studies with most interventions containing range of movement, strengthening and task specific exercises regardless of fracture type. Similarly, interventions for people with multiple or lower limb fractures often incorporated functional tasks, gait and balance training, and advice on return to activities. Value was also attributed to certain features of the interventions, and these are discussed below.

Team approach

The literature showed flexibility in how interventions could be delivered, with roles not defined by profession but by the practitioner's skills, knowledge and training. In several studies, healthcare professionals undertook roles beyond their usual scope of practice. For example, physiotherapists [57] and sports therapists [59] were trained by clinical psychologists to deliver psychosocial interventions. Diversity in roles and recognition of transferable skills across the workforce has become increasingly common in healthcare [62,63], with different professions collaborating to offer holistic care and provide greater accessibility and flexibility in service delivery [64-66].

Person-centred

The literature highlighted the importance of person-centred rehabilitation designed to focus on the individual's needs, which could be vocational, recreational, or task-specific [34,49,58]. To achieve this, an essential component was goal setting to ensure the rehabilitation programme was relevant and the individual would engage [39,57]. Goal setting is an established practice within rehabilitation [67,68], however, it is important the individual is actively involved to ensure the process is meaningful and effective [69,70].

Psychosocial support

Psychological recovery was considered as important as physical recovery for people with multiple fractures. The literature emphasised the importance of psychosocial interventions for this population [37,57-59] and offered a variety of different components such as self-management and coping strategies, CBT, mindfulness, and stress management. In contrast, the studies investigating people with isolated upper limb and lower limb fractures focused solely on their physical recovery, with the exception of Archer et al. [ref]. This presents a potential gap in the

Table 2
Intervention descriptions based on the TIDieR checklist.

TIDieR criteria [29]	Description (n=number of studies)
Why (rationale)	• To improve physical function including range of movement, muscle strength, balance, proprioception, and sensation. • To improve long-term physical and psychological outcomes for survivors of trauma.
What – Materials	• Exercise-related e.g. resistance bands, gym balls, static bike • Specialist equipment e.g. antigravity treadmill, visual feedback training, virtual reality headsets • Communication aids e.g. exercise diaries, online platforms, video tutorials
What – Procedures	• Exercise-based interventions ($n = 15$), including eight studies using specialist equipment as an adjunct to standard rehabilitation. • Four studies compared manual therapy treatments such as joint mobilisations or desensitisation techniques, to other forms of physiotherapy or a placebo. [42-44,47] • Four studies investigated psychosocial interventions such as CBT, mindfulness, and self-management strategies in comparison to usual care. [37,57-59] • Two studies took an MDT approach to assessment and treatment. These interventions incorporated components such as exercise, functional activities and self-management strategies, however, the focus was on early coordinated care [34] and higher intensity of therapy input [39]. • Several studies highlighted the importance of making rehabilitation meaningful to the individual through person-centred goal setting and task-orientated, recreation or occupation-specific exercises and activities [34-35,39,45, 49-50,57,59].
Who provides	• Physiotherapists delivered most interventions ($n = 19$), including one study where clinical psychologists trained physiotherapists to deliver CBT intervention [57]. • MDT with physiotherapists, occupational therapists, social workers, clinical psychologists, and consultants in rehabilitation medicine ($n = 2$) [34,39]. • CBT therapists who could be social workers, psychologists, psychotherapists or counsellors [37]. • Sports therapists trained by a clinical psychologist [59]. • Professional acupuncturist delivered the TEAS intervention [46]. • Orthotist measured and fitted the IDEO used by military personnel [40].
How	• In-person, individual therapy sessions ($n = 21$). • One study used a combination of individual and group sessions [39]. • Three studies used virtual delivery by telephone and/or internet [37,57-58].
Where	• Outpatient physiotherapy departments ($n = 16$). • Outpatient therapy areas within specialist rehabilitation centres ($n = 2$) [46,49]. • Residential rehabilitation setting ($n = 1$) [39]. • Military medical facility ($n = 1$) [40]. • Orthopaedic outpatient clinic ($n = 2$) [34,59]. Both reported this as a limitation with a lack of privacy and time to spend with participants to deliver the intended interventions. • Virtual ($n = 3$) [37,57-58]. Vranceanu et al. [58] timed their initial session with the participant's orthopaedic clinic appointment, with all subsequent sessions delivered remotely.
When and how much	• Most interventions occurred within the first 12-weeks post injury ($n = 19$). • The most common schedule was two sessions per week delivered over a 6-week period. • Bouman et al. [39] delivered 84 sessions (individual and group). Their residential rehabilitation programme commenced within the first 12-weeks, but recruitment was open to people up to 6-months post injury. • Hsu et al. [40] recruited military personnel 1–2 years post limb salvage and did not describe the intervention's frequency or dose. • Busse et al. [37] described a CBT intervention comprised of seven modules with homework, which were worked through at the individual's pace. • Three studies evaluated a single treatment episode with pre and post treatment measures [36,41,47]. • Dose and intensity were dependent on the type of intervention used (see supplementary file 2). • Four studies did not report dose [40,41,47,59]. • Bouman et al. [39] reported the highest intensity with participants receiving a minimum of 5 h individual therapy per week, including hydrotherapy, plus up to 4 h of group occupational and recreational therapy per week and up to 4 h sports and fitness activity sessions per week, totalling $\geq$13 h per week.
Tailoring	• Physical interventions were titrated to the individual's fitness and ability ($n = 18$). • Psychosocial interventions were directed by the individual's needs and personal goals following an initial assessment. [37,57-59] • Safety alerts or protocols were used to ensure interventions did not negatively impact bone healing ($n = 4$) [38,41,46, 55].
Modifications	• Administrative modifications were reported in four studies [35,38,40,57] • Bouman et al. [99] developed a waiting list for their intervention and had to mitigate this by recruiting and training more therapists.
How well	• Eight studies reported adherence or acceptability. • Virtual CBT programme was rated 'very' or 'extremely' helpful [57]. • Virtual 'mind body and skills' programme was acceptable to 86 % participants [58] • Virtual reality headsets had positive Likert scores for acceptability, usability, and feasibility [41]. • Three studies reported high rates of adherence to their exercise programme [49-50,53] • Moseley et al. [51] found dissatisfaction with their intervention outcomes. • Zdziarski-Horodyski et al. [59] had poor adherence with a 75 % loss to follow-up.

literature, although several qualitative studies have been completed on this topic [2,5,71,72]. Future studies on complex fractures could benefit from reporting the effect of physical and psychosocial rehabilitation on outcomes.

This finding that psychosocial support is an important component within an intervention for complex fractures aligns with the evidence that orthopaedic trauma causes significant psychological distress leading to poorer outcomes [71,73,74] and a lasting impact on overall health and quality of life [1,2]. However, how best to package and deliver these psychosocial interventions remains an unanswered question with more research and stakeholder engagement recommended [34,37,59].

Supervised exercise

Most of the studies explored the effectiveness of different exercise interventions delivered by physiotherapists. This focus on physiotherapy corresponds with current practice in England and preliminary work in this field, including regional and national audits [16,75].

Supervised exercise by a trained professional was more effective than unsupervised [42,44,50], however, home exercise programmes were valuable with professional guidance [48]. These findings mirror wider orthopaedic research where the benefits of supervised versus unsupervised exercise programmes continues to be debated [76,77], with a particular focus on adherence and quality [78].

Only one study used a group setting to deliver rehabilitation activities [39]. The wider trauma and critical illness literature promote this approach, emphasising the benefits of peer support through shared experiences and altruism [79,80].

Although this scoping review has identified components of interventions used to rehabilitate adults with complex fractures, there

Table 3
Intervention category, components and fracture type.

Category	Intervention components	Fracture type
Exercise	• Static stretches [36,42,46,48,49, 52] • Range of movement exercises (passive and active) [34-35,38-39, 41-43,46-48,52-55] • Strengthening exercises [34-35, 38-39,49,50-52,54-55] • Task specific exercises [35,39,45, 49-50]	All fracture types
	• Aerobic training [34,39] • Group exercise classes [39] • Hydrotherapy [39]	Multiple fractures[1]
Manual therapy	• Joint and/or soft tissue mobilisations [42-47] • Oedema management including cryotherapy [43,45,49]	All fracture types excluding multiple fractures
	• Muscle energy technique (MET) [36] • Desensitisation techniques [47]	Upper limb fractures[2]
	• Proprioceptive neuromuscular facilitation (PNF) technique [46, 48]	Tibial plateau fractures and elbow fractures
	• Scar management [34]	Multiple fractures
Functional activities	• Gait training [35,39,43,45-46, 50-52] • Balance training [34-35,39,46, 51-52] • Functional activities e.g. walking, stairs, household tasks [34-35,39, 45,50]	Lower limb fractures[3] (including ankle[4]) and multiple fractures
	• Recreational / hobby specific tasks [39] • Vocational/ occupation specific tasks [39]	Multiple fractures
Therapy adjuncts	• Active controlled motion machine (ACM) [53] • Antigravity treadmill [38,45,54] • Intrepid Dynamic Exoskeletal Orthosis (IDEO) [40] • TecnoBody® device for visual feedback training [55] • Transcutaneous electrical acupoint stimulation (TEAS) [46] • Virtual reality headset [41]	Lower limb fractures (including ankle)
Psychosocial practices	• Advice on return to work, activities & sport [34,39,43, 50-52,57] • Person-centred goal setting [34-35,39,50,57,59]	Lower limb fractures (including ankle) and multiple fractures
	• Self-management strategies to grade activity and optimise function [34,37,57-59] • Advice on recovery – exercise, sleep, diet [34,37,39,57,59] • Pain and symptom management [34,37,57] • Cognitive behavioural therapy [34,37,57-58] • Mindfulness [37,57,59] • Coping strategies [37,57-58] • Stress management [39,57,59] • Trauma focused therapy including acceptance & resilience [34,39, 57,59]	Lower limb fractures (excluding ankle) and multiple fractures

[1]**Multiple fractures:** lower limbs or combination of upper & lower limbs, pelvic or acetabular [34,39,58-59], open or closed extremity fractures [37]. [2]**Upper limb fractures:** humerus [36,42,49], elbow joint [48], any upper limb fracture [47]. [3]**Isolated lower limb fractures:** ankle & hindfoot [44], femur [38,41,54], tibia [38,41,45-46], knee joint [55], lower limb, pelvic or acetabular [57], limb salvage [40]. [4]**Isolated ankle fractures:** unstable ankle fractures [53], complex & non-complex ankle fractures [35,43,50-52].

remain significant gaps in the evidence base and no guidance on best practice. In situations where the existing literature is insufficient to inform clinical practice, further research is advised [81]. However, considering the heterogeneity within this population, other research methods could be beneficial as an alternative to RCTs. Primary qualitative research [81], consensus with experts, including patients [82,83], and coproduction or codesign approaches [84,85] are recommended methods to manage complexity, and to develop effective interventions and best practice guidance.

Limitations

The literature on scoping reviews acknowledges that the balance between breadth and depth of analysis is a challenge [86,87] and consequently, it is possible that relevant information has been missed.

This review aimed to use rigorous and transparent methods for completion and reporting, however, there were some limitations. The review included references published in any language, but the searches were solely conducted in English. The forward citation search screened every hit related to the selected studies but only using the Google Scholar platform. The second reviewer (AH) completed 100 % screening, but only extracted data from 50 % of the selected studies. This was a pragmatic decision due to time and resource constraints. However, the reviewers (LS and AH) had good agreement on the data they both extracted.

Conclusions

The studies found varied in terms of population and approach, with a wide range of injuries, interventions and modes of delivery reported. Fidelity was poorly described, with only a third of studies reporting adherence or acceptability. There was inconclusive evidence to inform clinical practice and further research is advised. Considering the heterogeneous population, other research methods could be beneficial as an alternative to RCTs. Qualitative, expert consensus, and coproduction approaches are recommended methods to develop complex interventions and best practice guidance.

Despite the heterogeneity in fracture type, location and complexity, commonalities were found across the studies. Most interventions were exercise-based and delivered by physiotherapists. The majority contained range of movement, strengthening and task specific exercises; functional tasks; gait and balance training; and advice on return to activities. Value was attributed to components such as, a coordinated team approach, person-centred rehabilitation, supervised exercise and psychosocial support.

CRediT authorship contribution statement

Lucy Silvester: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anna Higo:** Validation, Data curation. **Rebecca S. Kearney:** Writing – review & editing, Validation, Supervision. **David McWilliams:** Writing – review & editing, Validation, Supervision. **Shea Palmer:** Writing – review & editing, Validation, Supervision.

Declaration of competing interest

RSK is co-chair of the NIHR Programme Grants for Applied Research (PGfAR) committee, a paid position in NIHR but unrelated to this research. She is also a previous chair of the NIHR West Midlands Research for Patient Benefit (RfPB) committee and member of the NIHR Health Technology Assessment (HTA) Clinical Evaluation and Trials Committee and NIHR Integrated Clinical Academic (ICA) doctoral committee. RSK has been awarded current and previous NIHR research grants. RSK is a co-investigator on grants funded by the Australian

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Supplementary materials

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