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Review

Telerehabilitation for community-dwelling middle-aged and older adults after musculoskeletal trauma: A systematic review

Maureen C. Ashe[1,2,3,*], Christina L. Ekegren[4,5,6], Anna M. Chudyk[7], Lena Fleig[8], Tiffany K. Gill[9], Dolores Langford[1,10,11], Lydia Martin-Martin[12] and Patrocinio Ariza-Vega[13,14]

[1] Centre for Hip Health and Mobility, Vancouver, Canada
[2] Department of Family Practice, The University of British Columbia, Canada
[3] School of Psychology, The University of Adelaide, South Australia, Australia
[4] School of Public Health and Preventive Medicine, Monash University, Melbourne, Australia
[5] Baker Heart and Diabetes Institute, Melbourne, Australia
[6] Alfred Emergency and Trauma Centre, Melbourne, Australia
[7] Department of Family Medicine, University of Manitoba, Canada
[8] Department of Natural Sciences, Health Psychology, Medical School Berlin, Germany
[9] Adelaide Medical School, Faculty of Health and Medical Sciences, The University of Adelaide, South Australia, Australia
[10] Vancouver Coastal Health, Canada
[11] Department of Physical Therapy, The University of British Columbia, Canada
[12] Department of Physiotherapy, Faculty of Health Sciences, University of Granada, Spain; Institute for Biomedical Research (ibs), Granada, Spain
[13] Department of Physical Medicine and Rehabilitation, Virgen de las Nieves University Hospital, Granada, Spain
[14] PA-HELP "Physical Activity for HEaLth Promotion" Research Group. Department of Physiotherapy, University of Granada, Granada, Spain

*** Correspondence:** Email: maureen.ashe@ubc.ca; Tel: +6046752574; Fax: +6046752576.

Abstract: *Background:* Musculoskeletal trauma at midlife and beyond imposes significant impact on function and quality of life: Rehabilitation is key to support early and sustained recovery. There are frequent barriers to attending in-person rehabilitation that may be overcome by the recent advances in technology (telerehabilitation). Therefore, we conducted a systematic review of published evidence on telerehabilitation as a delivery mode for adults and older adults with musculoskeletal

trauma. *Methods:* We followed established guidelines for conducting and reporting systematic reviews. We searched the following databases up to June 23, 2018: Cochrane Library, Cumulative Index to Nursing and Allied Health Literature, Embase, Google Scholar, MEDLINE (Ovid and PubMed), PsycINFO, and SportDiscus. We included publications across all available years and languages for community-dwelling adults (50 years and older) with musculoskeletal trauma; and interventions using the following delivery modes: Apps, computer, telephone, videophone, videoconference, webcam, webpage, or similar media. *Results:* Six studies met the inclusion criteria: Five studies for hip fracture (n = 260) and one study for proximal humeral fracture rehabilitation (n = 17). Four of the studies used telephone as the delivery mode, one used computer and another used video-conferencing. Two of the studies were pre-post with no comparator group, and the remaining four studies were randomized controlled trials with low or unclear risk of bias. Studies established some modes of remote delivery as feasible, but the generalizability of the findings were limited. Two studies observed significant between-group differences (favoring the intervention) for physical activity, quality of life, and self-efficacy. *Conclusion:* Very few studies exist that tested the effect of telerehabilitation for recovery after musculoskeletal trauma later in life. Given the global burden imposed by musculoskeletal trauma, this review underscores an important gap in clinical knowledge.

Keywords: systematic review; fracture; aging; telemedicine; technology; recovery

Abbreviations: ASCQ: Ambulatory Self-Confidence Questionnaire; BCT: Behavior Change Technique; CINAHL: Cumulative Index to Nursing and Allied Health Literature; DASH: Disability of the Arm, Shoulder and Hand; EQ5D-5L: EuroQoL—5 levels; IPAQ: International Physical Activity Questionnaire; IQR: Interquartile Range; MET: Metabolic Equivalent of Task; MFES: Modified Falls Efficacy Scale; PRISMA: Preferred Reporting Items for Systematic reviews and Meta-Analyses; RCT: Randomized Controlled Trial; SPMSQ: Short Portable Mental Status Questionnaire; WHO: World Health Organization; YPAS: Yale Physical Activity Survey

1. Introduction

The global burden of musculoskeletal trauma is substantial [1]. Home-based rehabilitation has the potential for maximizing recovery after discharge from hospital with musculoskeletal trauma, such as hip fracture [2]. There are barriers to delivery of publicly-funded home rehabilitation [3,4], possibly because it is resource intensive, and or because of a chronic shortage of clinicians [5], especially in rural communities [6]. Telerehabilitation is a promising delivery mode innovation because it could minimize barriers to providing health care management. It is defined as *"the provision of rehabilitation services at a distance using telecommunications technology as the delivery medium"* [7] *page 217* and can be delivered via a number of different modes, such as telephone, video (webcam, video-conferencing), mobile apps, web-based etc.

The field of telerehabilitation for managing health conditions, such as heart disease [8] and stroke [9,10] is growing. However, less is known about this delivery mode for the prevention or management of impairments or disability after musculoskeletal trauma (i.e., from falls and fractures)

in adults at midlife and older. Although a limited number of reviews are available [11,12] previous literature did not report or synthesize evidence on factors such as feasibility, generalizability, adherence or behavior change techniques employed—all key elements important to understand for future delivery of this mode of rehabilitation. Previous reviews included studies with participants who had musculoskeletal conditions such as osteoarthritis, and although this is also an important focus, it is distinct from the experience of adults and older adults who have an acute (unexpected) trauma such as fracture. Further, the populations may be different. Based on population-level data, patients who had an elective total hip replacement compared with patients who had surgery for low-trauma hip fracture were younger, had fewer co-morbidities, and there were more men [13]. These contextual factors may or may not present different challenges for delivering care remotely, but it signals the need to provide an evidence synthesis specific to adults and older adults with musculoskeletal trauma.

Therefore, the aim of this systematic review was to provide a synthesis of available evidence of telerehabilitation for adults aged 50 years and older who sustained musculoskeletal trauma. We anticipate that this new knowledge will extend current evidence on the management of recovery after musculoskeletal trauma, and highlight gaps in evidence to inform further research agendas for this all too common health condition for adults and older adults.

2. Methods

2.1. Protocol and registration

We completed a systematic review following the guidelines for conducting and reporting as established by the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) [14]. Prior to starting the review, we registered the title and methods on PROSPERO CRD42017083447. Our review question was: What is the effectiveness of telerehabilitation for community-dwelling adults and older adults with musculoskeletal trauma?

2.2. Systematic review team members

Our review team has representation from the academic and clinical communities, with representation from Australia, Canada, Germany and Spain. In particular, our review team included registered and or practicing clinicians working in musculoskeletal health (MCA, CLE, TKG, DL, LM, PAV) who provided an important perspective for guiding the review process. Our team also includes a health psychologist (LF) who has a significant track record using behavior change theories. Many of the authors previously published numerous systematic reviews (MCA, CLE, AC, LF).

2.3. Eligibility criteria (concepts)

We only included peer-reviewed publications, and studies that represented the following concepts: *Population:* Community-dwelling adults (50 years and older) with musculoskeletal trauma; *interventions:* Telerehabilitation using apps, computer, telephone, videophone, videoconference, webcam, webpage, or similar media; *comparator:* Usual care (in-person rehabilitation) or no

rehabilitation; and *type:* Randomized controlled trials (RCT), controlled clinical trials, controlled before and after studies, interrupted time series, and feasibility/pilot or implementation studies.

2.4. Information sources and searches

One author (MCA) developed the search strategy and the other co-authors reviewed it for completeness and comprehensiveness. We searched the following electronic databases for all years until June 23, 2018: Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Database of Systematic Reviews, Embase, Medline (Ovid and PubMed), PsycINFO, and SportDiscus. Figure 1 is the search strategy used for Ovid MEDLINE. We also searched ClinicalTrials.gov and the WHO clinical trial registry (June 30, 2018) and conducted a focused search in Google Scholar for the following keywords in the title only: (1) fracture AND (telephone OR interview OR interviewing OR telerehabilitation) NOT protocol; and (2) fracture AND telephone OR telerehabilitation. We uploaded the identified citations into Covidence (Covidence systematic review software, Veritas Health Innovation, Melbourne, Australia) which removed duplicate references. For all studies accepted at the full text level, we conducted a forward citation search, and reviewed the reference lists. For the reference lists, one author (MCA) screened them and excluded any webpages, reviews, and references to methods/outcome measures, before uploading the remaining citations to Covidence. We included literature from all years and in all languages. If a publication was written in a language other than English, we requested an English version from the authors, or used Google Translate and resources within the team.

Database: Ovid MEDLINE (R) Epub Ahead of Print, In-Process & Other Non-Indexed Citations, Ovid MEDLINE (R) Daily and Ovid MEDLINE (R) <1946 to Present> Search Strategy:

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1 (mhealth or ehealth).mp. (4524)
2 telehealth.mp. or telemedicine/ (19004)
3 telephone.mp. or telephone/ (55472)
4 telemedicine/ or telerehabilitation/ or telerehab.mp. (17765)
5 (infomatics or informatics).mp. or *public health informatics/ or *informatics/ or internet.mp. or internet/ (110395)
6 strength.mp. or muscle strength/ (273238)
7 postural balance/ or balance.mp. (223487)
8 function.mp. (1947475)
9 quality of life.mp. or "quality of life"/ (286506)
10 fracture.mp. (182182)
11 ((foot or ankle* or hip* or knee* or leg* or thigh* or limb* or arm* or elbow* or forearm* or hand* or wrist* or shoulder* or neck* or back* or pelvis* or orthopaedic* or orthopedic*) adj3 (fractur* or injur* or trauma*)).tw. (88158)
12 exp fractures, bone/ (168880)
13 exp multiple trauma/ (12048)
14 exp musculoskeletal system/ (1344658)
15 "wounds and injuries"/ (71969)
16 1 or 2 or 3 or 4 or 5 (179470)
17 6 or 7 or 8 or 9 (2603627)
18 10 or 11 or 12 or 13 or 14 or 15 (1595130)
19 16 and 17 and 18 (691)

Figure 1. Search strategy for Ovid MEDLINE.

2.5. Study selection (Level 1, Level 2)

Following the search from the target databases (and removal of duplicates), two of four authors (MCA, CLE, AC, PAV) independently screened titles and abstracts of studies (Level 1), using Covidence. A third author reviewed any conflicts and made the final decision at Level 1 (LF). We repeated this process for the full text articles (Level 2) with two of five co-authors (MCA, CLE, AC, LF, TKG) who independently screened the full-text article. If we were uncertain if an intervention was considered telerehabilitation, we contacted the first author for confirmation.

2.6. Data collection process

We extracted the following information for included studies: Author, year, country, setting, injury, recruitment (including sampling frame) and retention, population, intervention (including mode of delivery), behavior change techniques, outcomes, and findings. We contacted authors, if necessary, to obtain additional information. One author extracted data (MCA) and four authors confirmed data extraction (PAV, CLE TKG, LM).

2.7. Risk of bias assessment (internal validity)

We used the Cochrane Risk of Bias tool [15] to assess the quality of included studies for RCTs. Two of three authors (MCA, TKG, PAV) independently reviewed each included study using Covidence to record their decisions. No author reviewed an included study that they authored, and final decisions were based on consensus between reviewers. We included all RCTs, regardless of the determined risk of bias, but planned to conduct a sensitivity analysis to determine the effect of excluding studies with higher risk assessments, if possible. For the category of blinding of personnel and participants, we used the Cochrane Handbook (Chapter 8) to guide our evaluation for risk of bias [16]. Specifically, we did not want to unfairly judge studies based on challenges with blinding group allocation from participants and personnel, a known challenge for rehabilitation trials [17]. Therefore, two authors discussed whether knowledge of group allocation would cause a substantial change in behavior in one group over the other (e.g., high risk of bias).

2.8. Generalizability (external validity)

We reviewed included studies to search for sampling frame, recruitment and retention, and overall description of included study participants to determine the generalizability of the findings [18].

2.9. Summary measures

Our a priori outcomes of interest were independent living, quality of life, falls, fractures, adverse events, mobility, balance, physical function and capacity, physical activity and sedentary behavior, fear of falling, and implementation factors: Feasibility, adherence, and behavior change techniques (BCT).

2.10. BCTs

We proposed to list BCTs used within each study. If study authors provided a published list of BCTs we included them in the overall description, otherwise, two authors (MCA, LF) independently reviewed each study and identified possible BCTs using the taxonomy established by Michie and colleagues [19]. We calculated Cohen's [20] Kappa statistic to estimate inter-rater reliability of identified BCTs used within the interventions.

2.11. Synthesis of findings

A priori we proposed to conduct a meta-analysis, if data were available and it was appropriate, following established guidelines (e.g., assess for statistical and clinical heterogeneity, determine use of random or fixed effects model based on available data, conduct sensitivity analyses, etc.). If it was not appropriate to conduct a quantitative synthesis, we planned to provide a narrative summary of the findings based on the population, intervention, and results. If possible, we proposed to conduct subgroup analyses for women/men and/or different types of delivery modes for interventions (e.g., telephone, online video).

2.12. Managing bias and potential conflict of interest

Throughout the review process, team members strived to reduce unconscious bias. We registered our protocol prior to starting, and followed standard systematic review guidelines with two reviewers who independently adjudicated potential publications at Levels 1 and 2, and assessed study risk of bias. If we were uncertain of a study design or intervention, we emailed the corresponding author for clarification. In addition, no author of an included study assessed its risk of bias. This was an unfunded study and authors stated no known conflicts of interest.

3. Results

3.1. Study selection

We conducted a comprehensive systematic search for evidence across several databases including all years and languages. Figure 2 presents the flow diagram of citations reviewed at Levels 1 and 2, with reasons for excluding citations at Level 2.

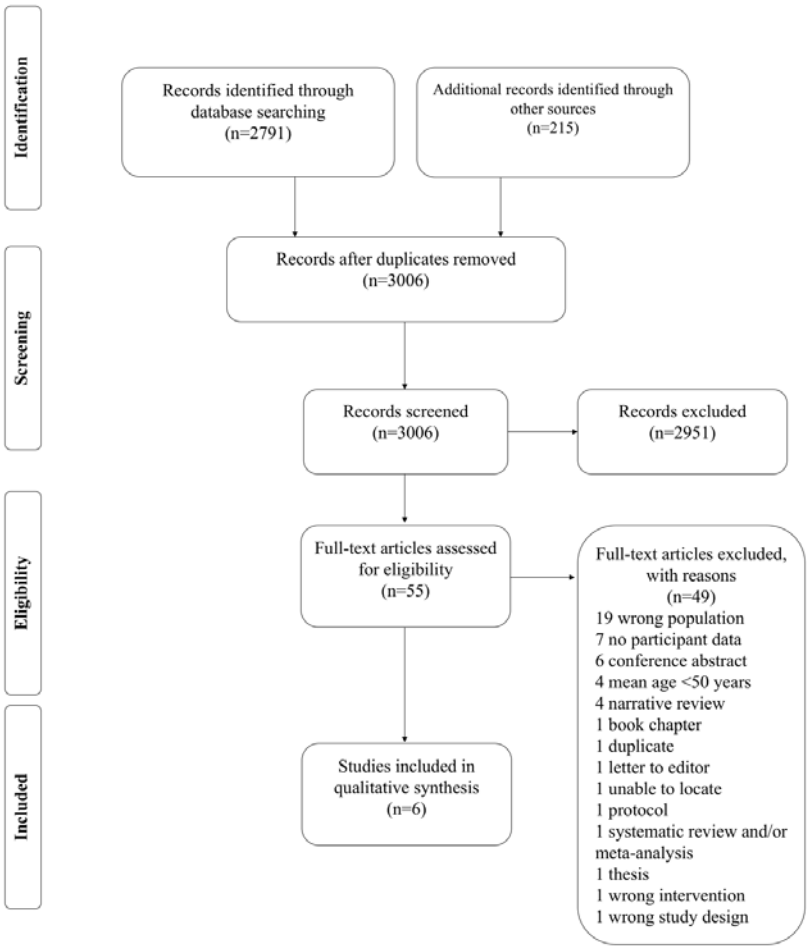

Figure 2. PRISMA flow diagram.

3.2. Study characteristics

There were six studies [21–26] included in this review representing 277 participants, and all but one study [26] was conducted with older adults with hip fracture. Four [22–25] of the six studies were RCTs with two pre-post studies [21,26]. Studies were conducted in several different countries including Australia (n = 1) [24], Canada (n = 2) [23,26], Italy (n = 1) [22], Thailand (n = 1) [25] and USA (n = 1) [21]. Four of the studies used telephony as the delivery mode [22–25], one used a computer [21] and another used video-conferencing [26]. One study used telephone and face-to-face delivery of the intervention [25]. Table 1 provides a description of the included studies.

3.3. Risk of bias

We only included the four RCTs [22–25] in the assessment. They had predominantly low or unclear risk of bias across items. For determining the risk of bias related to blinding of participants and personnel, we judged that the study by Di Monaco and colleagues (single phone call) [22] would not initiate a substantial change in behavior. In contrast, for the remaining three studies it was

difficult to untangle if the lack of blinding would increase risk of bias because of the design of the studies and interventions. Figures 3A, B summarize risk of bias overall and for individual studies.

3.4. Generalizability of findings

Almost all of the studies (5/6) were conducted in older adults recovering from hip fracture. All participants were community-dwelling and did not have dementia or low cognition scores; most participants were older white women. Only three studies reported their sampling frame with recruitment rates ranging from 19–74% for all possible participants, and 38–94% of all eligible participants. Participant retention ranged from 71–100% (Table 2).

3.5. Implementation factors and BCTs

All interventions were completed in six months or less, but few studies reported a detailed description of the intervention, and its implementation. Only the two pre-post studies reported on participants' satisfaction. Only one study [23] listed the intervention BCTs. There was moderate to substantial agreement between the raters ($\varkappa$ = 0.57–1.0) [27] for adjudication of BCTs in the remaining five studies. Of the 93 behavior change techniques [19], 28 different techniques were identified within the included interventions (Table 3). The majority of BCTs identified belonged to the clusters goals and planning, repetition and substitution, and social support. Interventions were complex and the number of identified techniques used per study ranged from 4 to 17 (BCTs/study [4, 15]). The most popular BCTs included in the interventions were behavioral practice (83.3%), credible source (83.3%), and unspecified social support (83.3%), followed by instruction on how to perform the behavior (66.7%).

3.6. Synthesis of results

There was heterogeneity in outcome variables within the included studies precluding combining data quantitatively, therefore we only conducted a narrative summary of the identified evidence. For example, physical activity was measured in two RCTs [24,25], however one study used self-report [25], and the other study used activity monitors [24], with different outcomes.

Overall studies ascertained feasibility for remote delivery via telephone and computer/online based modes for the target population, and some studies observed significant differences between groups (favoring the intervention). For example, based on two studies [21,26], there were statistically significant pre-post differences noted for exercise self-efficacy [21], function [21,26], physical activity [21], and quality of life [21]. In the four RCTs [22–25] there were significant between group differences in two trials only for exercise self-efficacy [25], falls self-efficacy [24], physical activity [24,25], and quality of life [24] (Table 4).

Table 1. Description of included interventions.

First Author Year Country Fracture location	Study design Methods	Population N = group Age (mean, range) W:M	Control	Intervention Type, Dose and Duration	Intervention Delivery
Bedra [21] 2015 USA hip	Feasibility study	N = 10 77 (9) y (65–88 y) 6:4	N/A	Home Automated Tele-management (HAT) system: Requested participants complete individualized exercises daily 30 days	computer and telephony
Di Monaco [22] 2015 Italy hip	RCT	N = 153 (78 intervention-75 control) 78 (7.2) y 169:0	Usual multidisciplinary hospital care	Usual multidisciplinary hospital care, and one telephone call (median 18 days) post-discharge (median duration 35 minutes (IQR 25-43) 6 months	telephony
Langford [23] 2015 Canada hip	Pilot RCT	N = 26 (11 intervention-15 control) 82 (61–97 y) 19:11	Usual multidisciplinary hospital care + education	Usual multidisciplinary hospital care + education, and up to 5 telephone calls (at home) 4 months	telephony
O'Halloran [24] 2016 Australia hip	RCT	N = 25 (13 intervention-12 control) 82 y + 21:9	Usual care	Usual care and eight 30 minute weekly motivational interviewing sessions 8 weeks	telephony
Suwanpasu [25] 2014 Thailand hip	RCT	N = 46 (23 intervention-23 control) 75 (8) y 35:11	Usual care and education	Usual care, education and physical activity enhancing program: 4 phases including 5 sessions in the first 7 weeks of surgery using both face-to-face and telephone contact. 6 weeks	telephony and face-to-face

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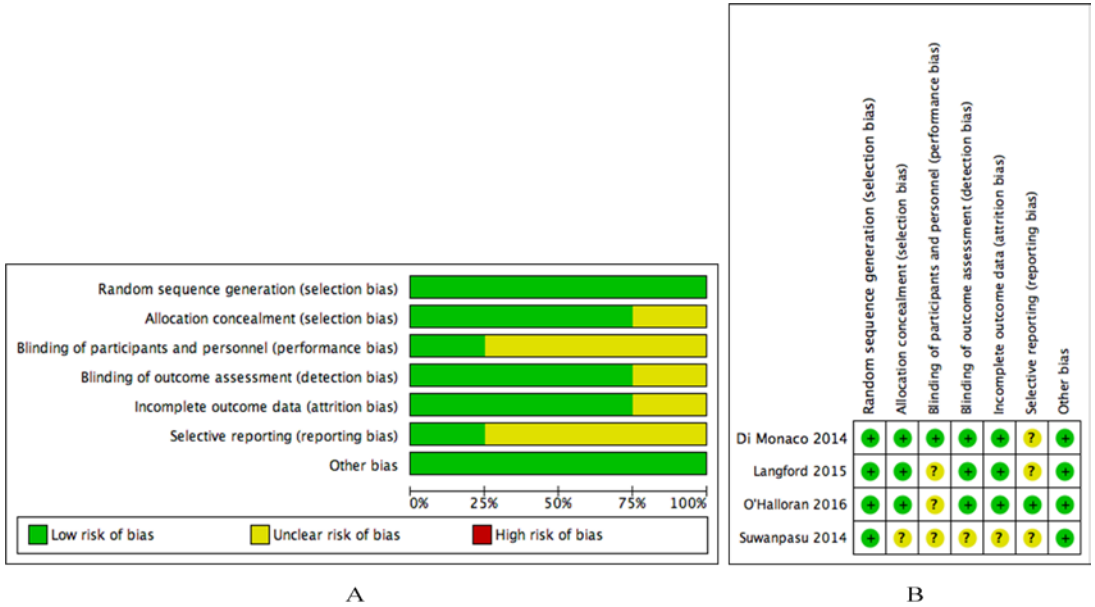
First Author Year Country Fracture location	Study design Methods	Population N = group Age (mean, range) W:M	Control	Intervention Type, Dose and Duration	Intervention Delivery
Tousignant [26] 2014 Canada proximal humerus	Pilot study	N = 17 65 (11) y 15:2	N/A	Individualized treatment/exercise program of 11 sessions for 30 to 45 minutes delivered by a PT, plus home exercises 8 weeks	video-conferencing

BCT: Behavior change techniques; IQR: Interquartile range; RCT: Randomized controlled trial; W:M: Number of women and men.



Figures 3. A: Risk of bias overall; and B: For individual randomized controlled trials.

Table 2. Study factors related to generalizability of the findings within the target population.

Study fracture location	Sampling frame	Recruitment location Time since fracture at enrollment	Other factors	Recruitment and retention rates	Description of participants who completed study
Bedra [21] 2015 Hip fracture (surgical repair)	Consecutive recruitment of community-dwelling older adults 65 years and older	Orthopaedic clinics or physical therapy centers Mean (SD) 159 (143) d since fracture	Dates for sampling frame not reported Cognition: Mini Mental Examination 27 (2) at baseline	Recruitment: N = 14 Rate not reported Retention: n = 10/14 (71%)	N = 10 Age: 77 (9) y^ Education: 11(4) y Ethnicity: 9/10 (90%) white Sex: 6/10 (60%) women
Di Monaco [22] 2015 Hip fracture (surgical repair)	Consecutive recruitment of women 50 years and older admitted to hospital	Physical medicine and rehabilitation hospital Recruited during hospital stay	Sampling frame based on 17 months Cognition: Mini Mental Examination >25 points at baseline	Recruitment: N = 169 All participants: 169/228 (74%) Eligible participants: 169/179 (94%) Retention: 153/169 (90%)	N = 153 Age: 79 y* Education: Not reported Ethnicity: White Sex: Women
Langford [23] 2015 Hip fracture (surgical repair)	Consecutive recruitment of community-dwelling older adults 60 years and older	Acute orthopaedic hospital ward Recruited during hospital stay	Sampling frame based on 6 months Cognition: No physician diagnosis of dementia	Recruitment: N = 30 All participants: 30/159 (19%) Eligible participants: 30/72 (42%) Retention: 27/30 (90%)	N = 26 Age: 81.5 y* Education: Not reported Ethnicity: Not reported Sex: 15 women, 11 men
O'Halloran [24] 2016 Hip fracture (surgical repair)	Recruitment of community-dwelling older adults 65 years and older	Four community rehabilitation sites (either home or center-based therapy) Recruited within 6 months after completion of rehabilitation	Dates for sampling frame not reported Cognition: Excluded if had more than two errors on screening with SPMSQ	Recruitment: N = 30 All participants: 30/147 (20%) Eligible participants: 30/79 (38%) Retention: 25/30 (83%)	N = 25 Age: 82.7 y* Education: Not reported Ethnicity: Not reported Sex: 21 women, 4 men

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Study fracture location	Sampling frame	Recruitment location Time since fracture at enrollment	Other factors	Recruitment and retention rates	Description of participants who completed study
Suwanpasu [25] 2014 Hip fracture (surgical repair)	Recruitment of older adults 60 years and older	Hospital ward Recruited during hospital stay	Study dates 14 months Cognition: 17.28/19* Chula Mental Test	Recruitment: N = 43 Rate not reported Retention: 43/43 (100%)	N = 46 Age: 75.2 (8.4)^ y Education: 14/43 completed high school higher education Ethnicity: Asian Sex: 25 women, 18 men
Tousignant [26] 2014 Proximal humerus fracture (no surgery)	Recruitment of adults proximal humerus fracture	Recruited from hospital orthopaedic department	Dates for sampling frame not reported Cognition: Not reported	Recruitment: N = 21 Rate not reported Retention: 17/21 (81%)	N = 17 Age: 65 (11)^ y Education: 13 (4) y Ethnicity: not reported Sex: 15 women, 2 men

^age mean (SD); *average of both groups; SPMSQ: Short Portable Mental Status Questionnaire.

Table 3. Identified BCTs included for interventions.

Identified behavior change techniques grouped in clusters	*k out of 6 studies*
1 Goals and planning	
1.1. Goal setting (behavior)	2
1.2. Problem solving	1
1.3. Goal setting (outcome)	2
1.4. Action planning	1
1.5. Review of behavioral goal	1
1.6. Discrepancy between current behavior and goal	1
2 Feedback and monitoring	
2.1. Monitoring of behavior by others without feedback	1
2.2. Feedback on behavior	3
2.3. Self-monitoring of behavior	2
2.4. Self-monitoring of outcome(s) of behavior	1
3 Social support	
3.1. Social support (unspecified)	5
3.2. Social support (practical)	1
3.3. Social support (emotional)	1
4 Shaping knowledge	
4.1. Instruction on how to perform the behavior	4
4.2. Information about antecedents	1
5 Natural consequences	
5.2. Salience of consequences	3
5.3. Information about social and environmental consequences	1
6 Comparison of behavior	
6.1. Demonstration of the behavior	3
6.2. Social comparison	1
7 Associations	
7.1. Prompts/Cues	1
7.5. Remove aversive stimuli	1
8 Repetition and substitution	
8.1. Behavioral practice/rehearsal	5
8.7. Graded tasks	2
9 Comparison of outcomes	
9.1. Credible source	5
9.2. Pros and cons	1
11 Regulation	
11.1. Pharmacological support	1
11.2. Reduce negative emotions	1
12 Antecedents	
12.1. Restructuring of physical environment	1

Note: *k*, number of studies to use BCT; grey shaded areas refer to the clusters of the taxonomy [19].

Table 4. Summary of outcomes from the included studies. Outcomes are presented as differences between groups, except for studies by Bedra and Finklestein 2015 [21] where pre-post intervention results are presented, and Tousignant et al., 2017, where results are presented as difference for pre-post intervention [26]. Square brackets indicate 95% Confidence Intervals, and round brackets indicate standard deviation.

First Author Year Country	Independent living	Quality of life	Falls, fractures or adverse events	Mobility or Physical function	Physical activity	Fear of falling or Self-efficacy	Adherence	Feasibility Satisfaction
Bedra [21] 2015 USA	*Modified Barthel Index* 95(6); 99(2) p = 0.10	*SF-36* Physical Functioning p = 0.009; Social Functioning p = 0.01; No significant between time differences for other sub-components		*Lower Extremity Functional Scale* 55 (16); 63 (13) p = 0.03	*YPAS (hr/wk)* 24 (14); 31(14) p = 0.04	*Exercise self-efficacy* 6 (3); 9 (1) p = 0.01	*Average exercise frequency/day* 87–97%	*Satisfaction questionnaire* 27 (4); 31 (0.5) p = 0.04
Di Monaco [22] 2015 Italy	*Barthel Index* No differences between groups at 6 months		*Proportion of people who fell* No differences between groups at 6 months: Intervention group RR 1.06 [0.48, 2.34] 3 intervention and 1 control group participant fractured				*Recommendations* At 6 months mean advice followed (by number of items) was intervention 75 (23)% compared with 71 (23)% control group p = 0.29	

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First Author Year Country	Independent living	Quality of life	Falls, fractures or adverse events	Mobility or Physical function	Physical activity	Fear of falling or Self-efficacy	Adherence	Feasibility Satisfaction
Langford [23] 2015 Canada		*EQ5D-5L* No difference between groups	*Prospective falls diaries* One participant in each group fell twice	*Gait speed (m/s)* No difference between groups		*Short-form Falls Efficacy Scale—International* No difference between groups		
O'Halloran [24] 2016 Australia	*Independent living* No differences between groups	*Assessment of Quality of Life Instrument 8-D* Favored intervention group Psychometric p = 0.015; Psychosocial p = 0.007; Mental health p = 0.039; Coping p = 0.005; Self-worth p = 0.023		*de Morton Mobility Index* No differences between groups	*activPAL activity monitor* Favored intervention group 1237 [12, 2463]$^{Steps/day}$ p = 0.048 14.7 [0.6, 28.8]$^{mins/day}$ p = 0.042	*mFES* *ASCQ* mFES 1.1 [0.3, 1.9] p = 0.007 ASCQ 1.6 [0.3, 2.9] p = 0.015	*Number of sessions received* 12/13 received 8 sessions and 1 participant had 7 sessions. Average session duration = 30 min	

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First Author Year Country	Independent living	Quality of life	Falls, fractures or adverse events	Mobility or Physical function	Physical activity	Fear of falling or Self-efficacy	Adherence	Feasibility Satisfaction
		no significant between time differences for other sub-components						
Suwanpasu [25] 2014 Thailand					*IPAQ* Favored intervention group $961.37^{MET/min/wk}$ $p < 0.01$	*Self-efficacy* Favored intervention group 8.35 score $p = 0.02$		
Tousignant [26] 2014 Canada				*Upper limb function DASH* 42.1 (11.4) $p < 0.001$				*Health Care Satisfaction questionnaire* Global score 82 (7)

4. Discussion

Globally, there is a large and growing population of adults and older adults who sustain musculoskeletal trauma each year [1]. Rehabilitation and resumption of usual activity is imperative for recovery and avoidance of further deterioration. Although delivering health care remotely using technology has increased considerably in the past two decades [28], we highlight a gap in knowledge for musculoskeletal trauma rehabilitation. In this systematic review, we only identified six studies that met the inclusion criteria. The existing evidence is based predominantly on telephony as the delivery mode, with limited generalizability to predominantly older community-dwelling women. An encouraging observation was the internal validity of RCTs, and use of behavior change theory and techniques within some studies. However, due to limited evidence and the heterogeneity of the outcome measures, we cannot make recommendations, at present.

A key take home message for this review is the apparent gap in evidence for telerehabilitation as a delivery mode after musculoskeletal trauma. This is in contrast to other clinical areas, such as stroke [10,29,30], cardiopulmonary [31–33], joint replacement [34,35], and multiple sclerosis [36,37]. Despite evidence on telerehabilitation for adults with chronic orthopaedic conditions [12], it is important to discern *"what works for whom and under what circumstances"* [38]: Implementation factors such as delivery mode for the intended population is an important factor for delivery, uptake and long term sustainability of an intervention. But, it is not entirely clear why there are fewer published studies in this area, but it may be related to the sudden and unexpected nature of traumatic events, and or the diversity of the population at risk [39]. Another consideration is that post-discharge pathways for routine rehabilitation may not clearly be defined for adults and older adults with musculoskeletal trauma [40]. Alternatively, hip fracture, for example, occurs later in life (the average age of participants in the included studies ranged from 75–82 years), and there may be a (mis) perception that online resources pose challenges [41]. However, older adults are a growing segment of the population using online resources: Approximately two-thirds of older adults are online, and many have internet access at home [42]. Despite barriers to remote care, e.g. cost of internet connection, security of online clinical discussions etc., access to online resources could support families and caregivers. For example, Nahm and colleagues developed a caregivers' online resource centre and discussion boards for hip fracture recovery [43].

There was limited support for some telerehabilitation interventions to increase physical activity, quality of life, and self-efficacy in older adults after hip fracture and proximal humerus fracture. However promising, these results should be viewed with caution, especially as the evidence was limited to mostly older community-dwelling women without significant cognitive impairment who have access to communication tools. Nonetheless, the collective evidence highlights feasibility of using remote delivery of care (mostly via telephone) after musculoskeletal trauma. In addition, the review highlights the use of an in-person clinical connection to build initial rapport prior to providing care remotely (e.g., in hospital, or attending rehabilitation or follow-up orthopaedic appointments) as part of the recruitment strategy. More detailed reporting on the implementation of telerehabilitation, such as using the Template for Intervention Description and Replication (TIDieR) checklist [44] is one way to encourage translation of important key ingredients for the successful delivery and uptake of an intervention to support future replication into practice.

A strength of some of the interventions was the use of behavior change theory and theory-based BCTs to support delivery and update of the interventions. Overall, we noted studies were complex and used many BCT (i.e., behavioral practice, credible source, social support). These "active ingredients" may have been important implementation factors. A recent systematic review of internet interventions for changing behavior noted that studies using more BCTs observed larger effect sizes [45]. However, it remains to be determined what BCTs (or combination of) were effective, and to determine the effect of delivery modes that use video, real-time observation and remote monitoring (via wearable sensors) for this population.

We acknowledge strengths and limitations with the systematic review process, and the evidence identified. Within the review process, we strived to be as comprehensive as possible and included studies from all years and in all languages. We used established guidelines to conduct the review and included three novel elements: BCTs, description of the generalizability of the evidence, and other implementation factors. However, the interventions and outcomes were too heterogeneous precluding meta-analyses. We are not able to draw any conclusions as there was limited evidence (based only on two RCTs using different types of interventions) that care delivered remotely may support an increase in participants' physical activity, quality of life, and self-efficacy. This review signals the need for more interventions to test the effectiveness of telerehabilitation following musculoskeletal trauma. In particular, data are lacking for middle-aged adults, men, and across ethnicities, languages, cognitive abilities, and the socioeconomic and health literacy spectrum.

In conclusion, based on this systematic review of published peer-reviewed literature, we identify a gap in knowledge for telerehabilitation for adults at midlife and older who experience musculoskeletal trauma. The existing evidence is a robust base from which to build clinical knowledge and develop, test and implement innovations. Future directions should consider using behavior change theory and behavior change techniques, and include detailed information for replication. Taken together, this review indicates the need for more studies to test telerehabilitation following musculoskeletal trauma.

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Conflict of interest

The authors declare no conflict of interest.

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