Exercise prescription after fragility fracture in older adults: a scoping review

Lynne M. Feehan*,

Department of Physical Therapy, University of British Columbia, Vancouver, BC, Canada

Charlotte A. Beck,

Woodward Biomedical Library, University of British Columbia, Vancouver, BC, Canada

Susan R. Harris,

Department of Physical Therapy, University of British Columbia, Vancouver, BC, Canada

Donna L. MacIntyre, and

Department of Physical Therapy, University of British Columbia, Vancouver, BC, Canada

Linda C. Li

Department of Physical Therapy, University of British Columbia; Arthritis Research Centre of Canada, Vancouver, BC, Canada

Abstract

Purpose—To identify and chart research literature on safety, efficacy or effectiveness of exercise prescription following fracture in older adults.

Methods—We conducted a systematic, research-user-informed, scoping review. The population of interest was adults aged ≥ 45 years with any fracture. ‘Exercise prescription’ included post-fracture therapeutic exercise, physical activity or rehabilitation interventions. Eligible designs included knowledge synthesis studies, primary interventional studies and observational studies. Trained reviewers independently evaluated citations for inclusion.

Results—A total of 9415 citations were reviewed with 134 citations (119 unique studies) identified: 13 knowledge syntheses, 95 randomized or controlled clinical trials, and 11 ‘other’ designs, representing 74 articles on lower extremity fractures, 34 on upper extremity, eight on vertebral, and three on mixed body region fractures. Exercise prescription characteristics were often missing or poorly described. Six general categories emerged describing exercise prescription characteristics: timing post-fracture, person prescribing, program design, functional focus, exercise script parameters and co-interventions. Upper extremity and ankle fracture studies focused on fracture healing or structural impairment outcomes, whereas hip fracture studies focused more on activity limitation outcomes. The variety of different outcome measures used made pooling or comparison of outcomes difficult.

*Corresponding Author: Lynne Feehan, c/o: Arthritis Research Centre of Canada, 895 West 10th Ave, Vancouver, BC, V5Z 1L7, Lynne.feehan@hiphealth.ca., Phone: 604-871-4546 Fax: 604-879-3791.

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Conclusions—There was insufficient information to identify evidence-informed parameters for safe and effective exercise prescription for older adults following fracture. Key gaps in the literature include limited numbers of studies on exercise prescription following vertebral fracture, poor delineation of effectiveness of different strategies for early post-fracture mobilization following upper extremity fracture, and inconsistent details of exercise prescription characteristics after lower extremity fracture.

Keywords

Exercise prescription; Fragility fracture; Older adults; Osteoporosis; Scoping review

Introduction

Many functional benefits are associated with exercise and physical activity participation by older adults, including improved cognitive, cardiovascular, strength and balance functioning as well as reduced risk for falls and bone density loss [1–9]. However, there is little information on the safety, efficacy or effectiveness of exercise prescription in older adults after a fracture. Following any fracture, older adults comprise a high-risk population that is likely to either benefit from, or be at risk from, exercise prescription throughout their recovery.

Epidemiologic studies show that increased fracture risk in adults begins around age 45, particularly in women, progressing notably more with each decade of aging [10–19]. About half of adult women and one-third of adult men will sustain a fracture [11–21]. Lifetime risk after age 50 for sustaining hip, distal radius or proximal humerus fractures is 25% in men and 55% in women [18]. Vertebral fractures are the most common type of fracture in adults over 50, with a prevalence of up to 25% in men and 35 to 50% among women [11, 13, 22]. As the proportion of older adults in the population increases, the number of fractures will also increase, placing a significant burden on direct healthcare usage and other indirect socioeconomic costs worldwide [23–25].

Fractures in older adults are often referred to as low trauma or fragility fractures because they tend to occur as the result of a fall from a standing height (or lower) or from a minimal trauma event that would not necessarily have resulted in a fracture in a younger person, or in the same individual at a younger age [26]. Fractures in older adults have also been referred to as osteoporotic fractures, as epidemiologic evidence has shown that low bone mineral density (BMD) is associated with an increased population-based risk of fracture; a BMD z-score of –1 SD increases overall population-based fracture risk by as much as 1.7 times [10, 27–30]. Advancing age is the strongest predictor of absolute fracture risk, with risk of ‘hip fracture’ for people with low BMD increasing twofold for each decade increase in age after the age of 50 [10]. Although fractures can and do occur in osteoporotic bone or in individuals with low BMD, as many as 50 to 85% of older adult fractures occur in people without osteoporosis [31–33].

The potential physical, emotional and social consequences of any fracture in an older adult are diverse and wide-ranging. Many fractures are managed surgically, with older adults more vulnerable to complications arising from surgery and hospitalization [34–39]. Poor

underlying bone health or poor general health can also adversely influence the quality and rate of fracture healing [40, 41]. Additionally, pre-fracture cognitive impairment, functional dependency and co-morbid conditions will negatively influence an older adult's ability to regain pre-fracture functioning [42–44]. Slow functional recovery and increased risk of progressive functional decline within the first year after fracture are most notable after hip fracture, with marked decline in physical, mental and emotional functioning at 3 months post-fracture with slow functional improvement over the next few months. One year after hip fracture, 50 to 55% of people will have a residual walking disability, with many never returning to pre-fracture or age-matched control functional status [45–50]. As well, 15 to 30% of people living independently in the community prior to hip fracture will be living in institutional care one year after hip fracture [27, 51].

Any fracture in older adults leads to a two-fold increase in subsequent fracture risk [27, 51–53]. Distal radius fractures are associated with a two-fold increase in subsequent fracture risk, particularly in men; occurring on average in healthier, younger and more active adults than other common fragility fractures [52]. Vertebral fractures are the most common fragility fracture in adults over 45, particularly in women and not uncommonly presenting following no known or a minimal traumatic event [11,54]. Vertebral fractures are associated with a four-fold increase in subsequent vertebral and other non-vertebral fracture risk. [11,54]. Following any fracture after age 60, 40 to 60% of survivors will experience another fracture within 10 years, with the majority of subsequent fractures occurring within one year of the initial fracture [55, 56]. Current osteoporosis practice guidelines recommend that any adult 40 or older who sustains any fracture should be investigated and treated for low BMD, as well as educated about lifestyle and nutritional factors, including exercise and physical activity participation, as a way of potentially modifying their subsequent fracture risk [26, 57,58].

Fracture in older adults also markedly increases risk of subsequent death. For 5 to 10 years after any low-trauma fracture (hip, vertebrae, other major and minor fractures) in adults over 60, there is up to a threefold increase in absolute mortality risk, with a subsequent fracture associated with an additional 5 years of increased absolute mortality risk [59]. Mortality rates after hip fracture are 11 to 23% at 6 months and 22 to 29% at 1 year after fracture, with men at greater risk for increased mortality in the first year, and both genders having an increased relative risk for mortality following hip fracture that is double that for the age-matched control population over the first 5 years [60–63].

In the past decade, there has been increasing interest in research on exercise for older people recovering from fragility fracture; however, the extent of this literature remains unclear. This poses a challenge for determining whether or not there is sufficient evidence to develop practice recommendations, whether or not a systematic review is feasible to conduct and, if there is a gap in knowledge, where that gap exists. A scoping review is a relatively new and developing methodology for synthesizing existing literature [64]. As such, there are a number of definitions of and approaches to conducting a scoping review [64–66]. Scoping reviews systematically chart or map the literature available on a topic, identifying key concepts, theories, sources of evidence and gaps in the research. Scoping reviews can also involve an integrated knowledge translation component, with ongoing iterative stakeholder

and research-user collaborations that inform the review process [64–67]. When there are a variety of sources and types of available evidence, scoping reviews can be used to describe key concepts within a specific research area, enabling identification of strengths and weaknesses within the literature, as well as emerging conceptual observations across a broad range of available evidence [67].

The purpose of this synthesis project was to conduct a comprehensive, systematic, research-user-informed scoping review to identify and chart the breadth of literature related to the *safety (potential risks), efficacy or effectiveness* of exercise prescription following any fracture in older adults and to identify areas for future systematic reviews [64–69].

Methods

This scoping review involved five steps: (1) defining a research question; (2) comprehensive and systematic identification of relevant studies across a broad range of potential evidence; (3) independent and objective screening and selection of studies for inclusion; (4) extraction and charting of the data according to key concepts identified; and (5) and summarization of the findings for clinical relevance and future research [64–67]. This review was also informed at each stage by iterative consultations seeking input from potential research-users including physical and occupational therapy clinicians, physical therapy decision-makers, osteoporosis consumers and experts in the areas of osteoporosis and musculoskeletal knowledge syntheses research (Figure 1). These consultations included national video-conference, teleconference, small group and one-to-one consultations [See Acknowledgments for a complete listing of the research team and collaborators in this study]

Research Question

The scoping review research question was defined using the PICOS (Population-Intervention-Comparison-Outcome-Study Design) format. The initial elements of the PICOS question were defined through consensus of the core group of the research team (LF, CH, SH, DM, LL) and subsequently reviewed by the research team and clinician collaborators to further refine the operational definitions, the primary health outcomes of interest and the key search terms to ensure clinical relevance and comprehensiveness of the scope of the search for this review.

The *population of interest* was defined as adults middle aged 45 or older (45 years) with any fracture within the previous year. The population of interest was extended to also include frail elders, fallers, and those with low BMD or osteoporosis, as these were populations of adults also likely to have identifiable subgroups that may have sustained a recent fracture.

The *intervention* of ‘exercise prescription’ was broadly defined as physical activity, exercise or active rehabilitation prescribed by a physician, physical therapist or occupational therapist, or other allied health professional [70]. The concept of ‘exercise prescription’ was broadly defined to fit with concept of exercise prescription as defined by ACSM position statement (1999) [71] as “the process whereby a person’s recommended regimen of physical

activity is designed in a systematic and individual manner.” Physical activity was defined as bodily movement produced by contraction of skeletal muscles that leads to increased energy expenditure, whereas exercise was defined as planned, structured and repetitive movements focused on improving or maintaining physical fitness [2]. Using the framework of the International Classification of Functioning, Disability and Health (ICF) [72], therapeutic exercise was defined as exercise prescribed by a medical (physician), rehabilitation (physical therapist or occupational therapist), or other allied health professional to address an individual’s structural or functional impairments (e.g., in range of motion, flexibility, strength, balance), limitations in activity (e.g., activities of daily living, dexterity, walking speed/distance, walking up or down stairs), or restrictions in participation in life situations (e.g., work, sport, other life roles). Rehabilitation was also conceptualized broadly, similar to a definition provided by Wade (2005) as “an educational, problem-solving process that focuses on activity limitations and aims to optimize patient social participation and well-being, and so reduce stress on carer/family” [73].

The *comparison of interest* was no therapeutic exercise and/or physical activity and/or active rehabilitation or different therapeutic exercise and/or physical activity and/or active rehabilitation. The primary and secondary health *outcome measures* of interest were literature-based and broadly grouped a priori into four general categories related to the quality and rate of fracture healing, functional recovery, secondary risk reduction or cost/burden of care and are listed in Table 1.

A broad range of *study designs* was defined. Eligible study designs included randomized controlled trials (RCT), quasi-randomized clinical trials (Q-RCT), controlled clinical trials (CCT), prospective longitudinal cohort studies, retrospective case-control studies and other designs/primary studies if they represented a unique subgroup of older adults with fracture. In addition, we included all clinical practice guidelines (CPG) and systematic reviews (SR) on the topic.

Search strategy

Broad search strategies were developed to search the published and gray literature sources and were supplemented by alternative searching techniques to find studies on this topic. Initial searches were conducted in the following licensed databases from their inception to October 2008: MEDLINE, Pre-MEDLINE, EMBASE, CINAHL and Evidence Based Medicine Reviews (CENTRAL, Cochrane Database of Systematic Reviews and DARE). These search strategies used text words and relevant indexing terms to capture the broader concepts associated with ‘exercise prescription’, including ‘therapeutic exercise’, ‘physical activity’ and ‘active rehabilitation’ interventions within the first year following any fracture. The closest match to the characteristics of our population of interest [middle-aged to aged populations (> 45 years old)] was used for all electronic search strategies. There was no language restriction and following the initial searches in October 2008, all licensed database electronic searches were rerun approximately every three months from the previous search date up to a final search cut off of July 3, 2009. (Table 2)

Alternate electronic gray literature searches were conducted in a variety of sources to locate conference papers, theses and dissertations, clinical trials in progress and practice guidelines

not published commercially nor indexed in major bibliographic databases. In addition, the Physiotherapy Evidence Database (PEDro), the Occupational Therapy Systematic Evaluation of Evidence database (OTseeker), and the Canadian Physiotherapy Association database were searched for specific rehabilitation 'evidence-based-practice' literature (Table 2). All alternate gray literature electronic searches were initially searched at the outset of this review and then researched or updated throughout the duration of the scoping review by one or more members of the research team (LF, CB, SH) with a final search cut-off date of July 3, 2009.

Supplemental alternate searching included contacting key authors and researchers in this area, as well as the primary contact person for all potentially related trials in progress. For all full text articles reviewed other potentially relevant or related studies were identified in context, with review of the reference lists and with specific backward and forward citation tracking. As well, the online journal websites that published the included citations were hand searched for recent publications. This entailed a full review of the content of the previous two issues and any electronic publications ahead of press (if available), as well as a specific search of the full archives on the site for any other related publications or publications by the primary author(s).

Study selection

Titles and abstracts for all retrieved citations were screened for eligibility. If it was unclear or considered likely that the citation would meet the eligibility criteria, then the full citation was retrieved and reviewed for final screening for eligibility. Articles that passed the initial screening received a full review (Figure 2). At each level of citation screening, eight trained reviewers were paired to evaluate each citation and worked independently to apply inclusion/exclusion criteria in an un-blinded fashion using standardized and previously piloted forms.

Whenever possible, review pairings included a clinician/content expert paired with an academic/methodology expert. Conflicts were resolved through consensus or by a third independent reviewer if consensus was not reached. In the event of a non-English citation, a third reviewer fluent in the language worked in tandem with the review team to translate and interpret the citation content. To manage the large citation retrieval and high degree of duplication and to maintain the accuracy and integrity of screening this large volume of citations, we used a web-based electronic data capture (EDC) and data management provider [Trialstat Clinical AnalyticsTM].

Data extraction and sorting

For studies meeting final inclusion criteria, additional data were extracted by one reviewer and checked by a second reviewer. Citation data extraction included language and year of publication, publication source (journal name or other location), study design and fracture location(s) within the body. Citations were also retroactively tracked (CB, LF) to define the search strategy retrieval route, presence or absence in one of three primary licensed databases (MEDLINE, EMBASE, CINAHL) and whether or not the citation was actually

retrieved using the electronic search strategies. All citations were then sorted for uniqueness (e.g., more than one citation per study).

For all RCT and CCT studies, details of the strategy or approach to exercise intervention as they were described in the citation, as well as details of what the primary outcome measure(s) were, were extracted. These data were then sorted and categorized through consensus of the core group of the research team (LF, SH, DM, LL) into general categories of how the exercise prescription characteristics were described in the literature. These categorizations were then presented to the rest of the research team and our clinician collaborators to ensure clinical relevance and comprehensiveness in terms of adequately describing the breadth and scope of the characteristics of exercise interventions presented in the literature. For knowledge synthesis studies, the study objective, population(s) included and key evidence-informed 'exercise prescription' practice and research recommendations were extracted.

Results

Citation retrieval

The search strategy retrieved more than 15,000 citations. Following removal of duplications, this was reduced to 9,205 potentially relevant citations. An additional 210 references were located via alternate search methods for a total of 9,415 citations retrieved. Following title and abstract screening, 9,132 citations were excluded with 283 proceeding to full text review. Ultimately, 134 relevant citations were identified representing 119 unique studies. See Figure 2 for a flowchart on the literature retrieval, screening, selection and reasons for exclusion.

The final 134 citations were published in 60 periodicals, with 30 published in three journals: 15 in *Archives of Physical Medicine and Rehabilitation*, nine in *Journal of Bone and Joint Surgery* (British Edition) and six in *Osteoporosis International*. The year of publication for the retrieved citations ranged from 1972 to final cut off for this search (July 3, 2009), with 98 published in or after the year 2000. One hundred twenty-four papers were published in English, with four Chinese, three German, two Danish and one French language publication identified. See Appendix A for a complete listing of the details (authors, title, journal, year and language of publication) for each of the 134 citations retrieved in this scoping review.

Analysis of the 134 included citations determined that 127 were indexed in one or more of three primary licensed databases: MEDLINE, EMBASE and/or CINAHL (46 in all three, 35 in MEDLINE and EMBASE, 10 in CINAHL and MEDLINE, five in CINAHL and EMBASE, 11 unique to MEDLINE, nine unique to EMBASE and 11 unique to CINAHL). The remaining seven citations included two citations indexed only in EBM/CENTRAL. Notably, it was determined that 29 (21.6%) of the final citations were identified through alternate search methods including the five that were not indexed in any of the licensed databases, 13 that were missed by the electronic search strategy and 11 that were initially retrieved via the electronic search strategies and then subsequently rejected through the initial title and abstract screening process. See Appendix A for further details of method of

retrieval (e.g. licensed electronic database or alternate search strategy) for each citation retrieved in this scoping review.

Data sorting and charting

Initial findings were presented to the whole research team at an investigator video-teleconference meeting and also more broadly to physical therapy teleconference seminar participants from 91 physical therapy clinical facilities across Canada, in which participants were also invited to complete an informal follow up survey. Input from these collaborator and research-user meetings helped inform the final structure for describing and charting the relevant study characteristics and exercise prescription parameters identified in this scoping review, including: (1) describing the range (breadth) of fracture types and level-of-evidence (study designs) presented; (2) identifying characteristics of how different approaches or strategies for how exercise interventions following fracture in older adults were presented in any intervention studies; (3) examining the range (breadth) and focus of primary health outcomes reported in any intervention studies; and 4) summarizing the existing, evidence-informed, post-fracture ‘exercise-prescription’ clinical and research recommendations from related knowledge syntheses.

Fracture and study design characteristics—Seventy-four of the 119 unique studies were lower extremity fracture studies, 63 of which were hip fracture studies, seven involved ankle fractures, and the remaining four were “other” or mixed lower extremity fracture studies. Of the 34 upper extremity studies, 24 were distal radius fracture studies, seven involved the proximal humerus and three were mixed upper extremity fractures. The remaining studies included eight vertebral fracture and three mixed body region fracture studies. Thirteen of the 119 unique studies were knowledge synthesis articles, 72 were RCTs, 23 were CCTs and 11 were ‘other’ study designs (Figure 2). See Appendix A for further details of fracture region(s) and study design for each citation included in this scoping review.

Exercise prescription characteristics—Frequently, the specific details of the approach or strategies for exercise prescription within a given RCT or CCT study (n=95) were not described. Instead, it was common to have statements such as participants were seen or treated by a physical or occupational therapist, or participants were referred to therapy or were treated by a multidisciplinary team; frequently very limited details were available as to what the specific exercise, physical activity or active rehabilitation intervention or exercise prescription entailed.

From the details of the exercise interventions that were provided, six general categories were identified for how the exercise intervention characteristics after fracture in older adults were described in the literature. These included: (1) timing (e.g., number of weeks post-fracture) of the exercise intervention after the fracture; (2) expertise or training of the person(s) prescribing the exercise; (3) exercise program structure, such as method of instruction, degree of supervision, program design (e.g., individualized or standardized) and exercise setting or location; (4) level of functional focus for the exercise program, such as addressing an individual’s structural or functional impairments (e.g., range of motion, flexibility,

strength, balance), limitations in activity (e.g., activities of daily living, dexterity, walking speed/distance, walking up or down stairs), or restrictions in participation in life situations (e.g., work, sport, other life roles); (5) specific parameters of the exercise prescription script, such as dosage, (frequency/intensity), progression and adherence; and (6) other, non-exercise co-interventions, including other rehabilitation interventions such as use of electro-physical agents or manual therapy or other non-rehabilitation interventions such as diet, medication, counseling or other social support (Table 3).

These six general categories were not mutually exclusive, in that any one of the studies may have described one or more aspects of these general characteristics for the exercise intervention utilized in the study. Unfortunately, only ‘timing of exercise prescription post-fracture’ was reported across all intervention studies (n=95), although the exact timing for the exercise intervention was not consistently reported. Mapping of the distribution of the approximate timing of post-fracture exercise by fracture body region and study design is illustrated in Figure 3.

Primary health outcome characteristics—Exercise prescription in older adults after fracture has the potential to influence recovery across a broad range of health outcomes. The extracted health outcomes were sorted within four previously defined, general categories or domains, including the effect of exercise prescription on: (1) the quality and rate of fracture healing or post-fracture bone health; (2) the quality and rate of physical, cognitive/emotional and social functional recovery; (3) secondary fracture and post-fracture mortality rates; and (4) indirect or direct healthcare and socioeconomic costs or burden (Table 1).

From the 95 RCT or CCT studies, the primary outcome measure was a *fracture healing or bone health* outcome in 13 (13.7%) studies, a *functional (structural impairment or activity limitation)* outcome in 69 (72.6%) studies, a *prevention* health outcome in four (4.2%) studies and a *cost or burden* health outcome in nine (9.5%) studies. Notably, no study defined a primary health outcome focused on a person’s capacity to participate in their usual life roles (e.g., spouse, worker, grandparent, caregiver) within their normal living environments following a fracture [72]. Figure 4 depicts the trends for health outcome domain [healing/bone health, ICF functioning (impairment, activity, participation), prevention, cost/burden] for the primary outcome measures reported in each body region (lower extremity, upper extremity, vertebral and mixed).

Knowledge syntheses summary—There were 13 secondary/knowledge synthesis (CPG or SR) studies identified related to the examination of some aspect of exercise prescription (therapeutic exercise, physical activity, active rehabilitation) in an older adult fracture population [74–86]. Table 4 provides a summary of the purpose, population(s) included and the key ‘exercise prescription’ related practice and/or research findings or recommendations in each synthesis, including a footer note for citation details of any subsequent updated or new of knowledge syntheses published after the final July 3, 2009.

One study had a mixed fracture focus, including any fracture in older adults [74], whereas, the remaining 12 studies specifically focused on one type of fracture, including eight hip fracture [75–82], two ankle fracture [83, 84], one proximal humerus fracture [85] and one

distal radius fracture study [86]. There was no knowledge synthesis study found for vertebral fracture populations.

Six of the nine hip fracture-related syntheses examined the effectiveness of multidisciplinary, coordinated care in acute healthcare settings compared to standard or orthopedic care programs [74–79, 82]. Four of the nine hip-related studies [76, 78, 80, 81] examined the effectiveness of different elements or approaches to mobilization or exercise or physical therapy interventions following hip fracture. Although there were trends across all these studies toward more favorable outcomes after specialized, multidisciplinary care programs and more favorable ambulatory and functional outcomes following early mobilization with weight bearing/ambulation, aerobic, balance and strengthening exercises, there was still insufficient or conflicting evidence from randomized trials to be able to recommend any one mobilization strategy or exercise intervention over another after hip fracture. Key areas for further research related to exercise prescription following hip fracture included identifying which exercise interventions and/or components of a care program are likely to have long-term, cost-effective and beneficial impacts on functioning and health-related quality of life.

The two ankle fracture synthesis articles examined the effectiveness of early mobilization and/or other early rehabilitation interventions, with a primary focus on ankle fractures treated surgically [83, 84]. The upper extremity syntheses examined the effectiveness of early mobilization strategies following proximal humerus fracture [86] and rehabilitation interventions following immobilization of distal radius fractures [86]. Although none of these syntheses specifically included studies solely of older adult populations, a number of the included studies across all the syntheses did include adults with a mean age over 45 years. Although there were trends across these studies for faster recovery in mobility, functioning and pain reduction (without risk of increased complications) when using early post-surgical motion and/or weight bearing following ankle fractures and early motion and/or functional use following non-displaced proximal humerus fractures, there was still insufficient or conflicting evidence from randomized trials to be able to recommend any one early mobilization or exercise intervention over another. Recommendations for future research included the need for high quality research studies examining the long-term functional outcomes and cost-effectiveness of early mobilization strategies for both surgically-treated and conservatively managed ankle, proximal humerus and distal radius fractures.

Discussion

Given the significant personal, functional, and socioeconomic impacts associated with hip fractures worldwide [23–25], it was not surprising that the majority of the secondary knowledge syntheses (approximately 60%) and primary interventional studies (approximately 50%) identified in this scoping review focused on exercise prescription following hip fracture. Despite the large number of hip fracture studies, there were no definitive, evidence-informed practice recommendations identified for the best or most effective approaches or strategies for exercise prescription following hip fracture in older

adults. Similarly, there were no definitive, evidence-informed practice recommendations identified for any other type of fracture in older adults.

In general, the literature provided inadequate descriptions of the specific parameters or characteristics of exercise prescription following fracture. Exercise is a complex intervention and a major challenge to exercise prescription is the identification of the optimal exercise program elements or strategies that contribute to favorable treatment outcomes. Equally important is the identification of exercise program elements or strategies that do not contribute to more favorable outcomes or are not cost-effective. The different approaches or strategies for how ‘exercise prescription’ was presented in the literature were sorted into six general categories that could potentially influence the safety, efficacy or effectiveness of a post-fracture exercise intervention. However, only one of these general characteristics of how exercise prescription was described in the literature, the timing of the exercise intervention post-fracture, was able to be charted across all studies.

The majority (55%) of studies focused primarily on mobilization introduced within the first 3 to 4 weeks following fracture, which is consistent with our understanding of the adverse functional (structural impairment and activity limitation) consequences associated with limb immobilization [87]. The primary clinical concern with early post-fracture mobilization is the possibility of disrupting the quality and rate of fracture healing, potentially causing delayed union, non-union or mal-union. However, the basic science literature shows that limited or controlled micro-motion or physiologic loads introduced within the first few days after fracture improves both quality and rate of fracture healing [88]. This finding is consistent with trends identified in this scoping review suggesting that early mobilization, weight bearing and/or functional use introduced in the first few days following a fracture are not necessarily associated with higher rates of healing complications in surgically-treated hip and ankle fractures and in conservatively managed proximal humerus fractures in older adults. In fact, the clinical research literature suggests that early interventions create the potential for faster recovery of personal functioning.

Few studies examined exercise or physical activity participation introduced later than three months after fracture, a surprising finding given the diverse range of functional and general health benefits from exercise and physical activity participation in older adults [1, 2, 89]. After any fracture, older adults are at particular risk of progressive functional decline, secondary injurious falls and fracture, and mortality [27, 40–63]. In this high-risk population of adults following a fracture, it would be relevant to examine the safety, efficacy and effectiveness of exercise or physical activity participation in preventing further falls and/or improving bone health after fracture and also as a potential strategy for mitigating or slowing down the rate of functional decline following fracture [26, 90, 91].

Very few (approximately 10%) of the RCT and CCT studies included in this systematic review, examined health-care related costs as an outcome. Notably, none examined direct health-service or care-related costs in terms of an actual monetary value; rather, all reported surrogate indicators of health-service or care-costs, such as, differences in length of hospital stay, number of hospital re-admissions, number of care-visits, or number requiring institutional care. Additionally, only one of the knowledge synthesis articles [74] reviewed

specifically examined evidence for the cost-effectiveness of programs of care following fracture in older adults; concluding that there is no evidence for cost-effectiveness for any in-patient program of care following hip fracture. Because health-economic and other socio-economic factors would be crucial considerations for the adoption of new care strategies following fracture in older adults, this notable lack of studies examining the cost-effectiveness of exercise prescription following fracture is a significant limitation in the existing literature. In contrast, two recent systematic reviews [90, 92] and one recent mathematical epidemiologic model based on a critical literature review [93] have examined cost-effectiveness of falls prevention programs in at-risk older adults, including evaluations of exercise interventions focused on fall prevention. Recommendations from these studies suggest that the most cost-effective, exercise-related strategies for fall reduction in older adult populations are single exercise intervention strategies rather than multi-factorial intervention strategies. However, it is not possible to conclude that these same findings in terms of cost-effective exercise strategies for fall reduction would apply to older adults with already existing fractures, as the studies included in these reviews did not specifically incorporate samples of, and/or evaluate subgroups of, older adults who had already sustained fractures.

Interestingly, 95% of the final citations were indexed in one or more of three primary licensed databases: MEDLINE, EMBASE or CINAHL, consistent with the finding that orthopedic topics are generally well indexed or covered in primary licensed databases [94]. Despite being indexed in these databases, approximately 20% of the final citations in this scoping review were either missed in the search or excluded during the title and abstract screening; another 20% were not indexed at all in MEDLINE. These findings emphasize the importance of searching multiple licensed databases and conducting comprehensive and systematic alternate search strategies in order to define the true scope or breadth of allied health related research. Some issues with indexing of allied health literature that may have accounted for missed citations include: date and journal coverage of allied health literature indexed in the primary databases; availability of, or properly applied, allied health subject terms; and the speed with which rehabilitation literature is indexed [95–96]. Additionally, lack of ‘exercise prescription’ keywords in the titles and abstracts, as well as the appropriate application of subject words by indexers, may have contributed to exclusion by reviewers at the title/abstract screening level.

The search strategy used in this scoping review closely matched that of more focused systematic reviews and provides a structured process with transparent methodology for charting the breadth of the literature in a given area [64–69]. As with more focused systematic reviews, the process for conducting a comprehensive scoping review is complex and time consuming, involving a significant commitment by a number of people on the research team [64–67]. Identifying and defining the *full scope or breadth of the literature* in allied health requires comprehensive, systematic and updated electronic searches in multiple licensed databases, supplemented by comprehensive and systematic alternate search strategies [97]. The primary difference between a more focused systematic review and a scoping review is the much larger volume of citation retrieval and review involved in the scoping review, with the administration, management and tracking of the process of

screening the large number of citations facilitated by use of a web-based electronic data capture and data management system.

Limitations

The primary limitation of scoping reviews is that they do not involve quality assessment of the included studies. This limitation presents a potential for bias in which recommendations or syntheses of the literature arising from a scoping review may be based on variable levels of evidence and/or quality of citations used in the synthesis [64–67, 98]. As such, scoping reviews are generally not regarded as a final or definitive literature synthesis from which practice guidelines or policy decisions can be based. Rather, scoping reviews are conducted primarily for the purpose of identifying and mapping the breadth, rather than the quality, of current literature in an area of research with broad-reaching clinical relevance and/or diverse research directions [64–66, 98]. The strength of the present scoping review is that it was conducted with the same rigorous and transparent methodology used in more focused systematic literature reviews, with the added knowledge translation component of ongoing, iterative, research-user collaborations [64, 68, 69].

As with all knowledge syntheses, there are always new publications that will be subsequently identified. The final cut off for this review was July 3, 2009 and these are the data and summaries included in this study. The 12-month lag between the final literature search and manuscript submission means that potentially important literature that may inform the scope of this field further may have been missed. However, there are three ongoing systematic reviews in progress that have arisen from this scoping review which are continuing to conduct searches and any new RCT or CCT studies published since July 3, 2009 will be included in these systematic reviews (see Future research directions).

In addition, in a follow-up review of the two updated and one new knowledge synthesis studies published after July 3, 2009 (see Table 4 footer note) we determined that there were no new RCT or CCT studies included in any of the these studies that were not already identified in our scoping review. As such, there were no new or substantive changes to the recommendations regarding the potential efficacy or effectiveness of exercise prescription following fracture in older adults that would warrant a re-synthesis of the data presented in this scoping review.

Another issue for this and similar reviews is the limited number of non-English publications captured. This may reflect the few, non-English, allied health and orthopedic journals that are indexed in the licensed databases searched in this review [99] and may relate also to the lack of universality of access to all potentially available databases [95]. For this scoping review, databases for complementary and alternate medicine, such as AMED (Allied and Complementary Medicine Database), and databases of non-English publications, such as PASCAL (a multilingual, multidisciplinary, bibliographic database in Science, Technology and Medicine) or LILACS (Latin American and Caribbean Health Sciences Literature), were not used. A further consideration is the potential bias introduced in the search strategy when using English key words for concepts related to therapeutic exercise, physical activity and

rehabilitation interventions in the electronic search strategies, which may not necessarily translate directly into other languages.

Conclusion

Despite the extensive body of literature and the significant number of studies identified in this scoping review on exercise prescription after fragility fractures in older adults, there is no clear, consistent evidence to enable development of evidence-informed practice recommendations related to the safety, efficacy or effectiveness for any given approach or strategy for exercise prescription.

There are, however, consistent trends in the literature suggesting:

- Improved functional outcomes with acute, inpatient, multidisciplinary rehabilitation care programs following hip fracture.
- Better ambulatory and functional outcomes with early mobilization, weight bearing/ambulation, aerobic, balance and strengthening exercise interventions following hip fracture.
- Faster recovery in mobility, functioning and pain without risk of increased complications with early post-surgical motion and/or weight bearing following ankle fractures and early motion and/or functional use following non-displaced proximal humerus fractures.
- That supervised or formal therapy may be no more effective in regaining long term mobility and function than unsupervised or home exercise programs following a period of immobilization for distal radius fractures.

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Research Assistants:

- Cynthia MacDonald. Graduate Programs in Rehabilitation Sciences, University of British Columbia. Vancouver, BC, Canada
- Amy Kirkham. School of Human Kinetics, University of British Columbia. Vancouver, BC, Canada

Canadian Physiotherapy Association (CPA)/Decision Making Partner:

- Carol Miller. CPA Central Office. Ottawa, Ontario.
- National Membership Survey Participants
- National Teleconference Participants

Researcher/Academic Collaborators:

- Meena Sran. British Columbia Women's Health Centre. Vancouver, BC, Canada
- William Miller. Department of Occupational Sciences and Occupational Therapy. University of British Columbia. Vancouver, BC, Canada
- Darlene Reid. Department of Physical Therapy, University of British Columbia. Vancouver, BC, Canada

- Marie Westby. Graduate Programs in Rehabilitation Sciences, University of British Columbia. Vancouver, BC, Canada

Cochrane Collaboration - Musculoskeletal Group Collaborators:

- Jill Hayden. Department of Community Health & Epidemiology, Dalhousie University. Halifax. NS. Canada
- Jessie McGowan. Institute of Population Health, Ottawa Health Research Institute, Ottawa, ON, Canada
- Peter Tugwell. Department of Epidemiology & Community Medicine. University of Ottawa. Ottawa. ON. Canada

Consumer Collaborators – Osteoporosis Society of Canada (North Vancouver Chapter):

- Dorothy McNaughton. Vancouver, BC, Canada
- Ethel Cook. Vancouver, BC, Canada

Physiotherapy Clinician Collaborators:

- Alison Hoens. Physical Therapist, Providence Health Care, Vancouver, BC, Canada
- Fatima Inglis. Physical Therapist. Providence Health Care, Vancouver, BC, Canada
- Chris Palmer. Physical Therapist. Vancouver Coastal Health, Vancouver, BC, Canada

Translation Partners:

- Sarah Ewald (Zurich, Switzerland): Danish, German, Finnish
- Lisolette Clark (Vancouver, Canada): Danish
- Tanja Mayson (Vancouver, Canada); French and German

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Appendix

Appendix A: Complete listing of the final 134 citations included in this scoping review

Citation #	Authors Primary	Title Primary	Periodical Full	Pub Year	Language
1	Toussant EM, Kohia M	A critical review of literature regarding the effectiveness of physical therapy management of hip fracture in elderly persons	Journals of Gerontology Series A-Biological Sciences & Medical Sciences	2005	English
2	Handoll HH, Sherrington C, Parker MJ	Mobilisation strategies after hip fracture surgery in adults.	Cochrane Database of Systematic Reviews	*2006	English
3	* Chilov MN, Cameron ID, March LM	Evidence-based guidelines for fixing broken hips: an update	Medical Journal of Australia	2003	English
4	** Cameron ID, Handoll HHG, Finnegan TP, Madhok R, Langhorne P	Co-ordinated multidisciplinary approaches for inpatient rehabilitation of	Cochrane Database Syst Rev	*2001	English

Citation #	Authors Primary	Title Primary	Periodical Full	Pub Year	Language
		older patients with proximal femoral fractures.			
5	Halbert J, Crotty M, Whitehead C, Cameron I, Kurrle S, Graham S, Handoll H, Finnegan T, Jones T, Foley A, Shanahan M, Hip Fracture Rehabilitation Trial Collaborative Group	Multi-disciplinary rehabilitation after hip fracture is associated with improved outcome: A systematic review	Journal of Rehabilitation Medicine	2007	English
6	Beaupre LA, Jones CA, Saunders LD, Johnston DWC, Buckingham J, Majumdar SR	Best practices for elderly hip fracture patients - A systematic overview of the evidence	Journal of General Internal Medicine	2005	English
7	Chudyk AM	Systematic review of hip fracture rehabilitation practices in the elderly	Archives of Physical Medicine & Rehabilitation	2009	English
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63	Zuckerman JD	Hip-fractures in geriatric patients; results of an interdisciplinary hospital-care program	Clinical orthopaedics and related research	1992	English
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Citation #	Authors Primary	Title Primary	Periodical Full	Pub Year	Language
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71	Chapurlat RD, Bauer DC, Nevitt M, Stone K, Cummings SR	Incidence and risk factors for a second hip fracture in elderly women. The Study of Osteoporotic Fractures.	Osteoporosis International	2003	English
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Citation #	Authors Primary	Title Primary	Periodical Full	Pub Year	Language
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Citation #	Authors Primary	Title Primary	Periodical Full	Pub Year	Language
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119	Sherrington C, Lord SR, Herbert RD	A randomised trial of weight-bearing versus non-weight-bearing exercise for improving physical ability in inpatients after hip fracture.	Australian Journal of Physiotherapy	2003	English
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102_1	Hodgson SA, Mawson SJ, Stanley D	Rehabilitation after two-part fractures of the neck of the humerus.	Journal of Bone & Joint Surgery - British Volume	2003	English
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39_1	Crotty M, Whitehead CH, Gray S, Finucane PM	Early discharge and home rehabilitation after hip fracture achieves functional improvements: a randomized controlled trial.	Clinical rehabilitation	2002	English
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Citation #	Authors Primary	Title Primary	Periodical Full	Pub Year	Language
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Citation #	Authors Primary	Title Primary	Periodical Full	Pub Year	Language
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44_2	Shyu YI L, Liang J, Wu CC, Su JY, Cheng HS, Chou SW, Chen MC, Yang CT	Interdisciplinary intervention for hip fracture in older Taiwanese: Benefits last for 1 year.	Journals of Gerontology - Series A Biological Sciences and Medical Sciences	2008	English
45_1	Ziden L, Frandin K, Kreuter M	Home rehabilitation after hip fracture. A randomized controlled study on balance confidence, physical function and everyday activities	Clinical rehabilitation	2008	English
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46_1	Hauer K, Rost B, Rutschle K, Opitz H, Specht N, Bartsch P, Oster P, Schlierf G	Exercise training for rehabilitation and secondary prevention of falls in geriatric patients with a history of injurious falls.	Journal of the American Geriatrics Society	2001	English
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Citation #	Authors Primary	Title Primary	Periodical Full	Pub Year	Language
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* Year of most recent substantive amendment

* Update of 1999 version, Updated again January 2010

** This version was withdrawn in 2009 and replaced with: Handoll HH, Cameron ID, Mak JC, Finnegan TP.

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*** E-pub ahead of Published in Print 2010

Citation #	Region	Subregion	Study Design	Retrieval Route
1	Lower Extremity	Hip	Knowledge Synthesis	Licensed Database
2	Lower Extremity	Hip	Knowledge Synthesis	Licensed Database
3	Lower Extremity	Hip	Knowledge Synthesis	Licensed Database
4	Lower Extremity	Hip	Knowledge Synthesis	Licensed Database
5	Lower Extremity	Hip	Knowledge Synthesis	Alternate
6	Lower Extremity	Hip	Knowledge Synthesis	Alternate
7	Lower Extremity	Hip	Knowledge Synthesis	Licensed Database
8	Lower Extremity	Hip	Knowledge Synthesis	Alternate
9	Lower Extremity	Ankle	Knowledge Synthesis	Alternate
10	Lower Extremity	Ankle	Knowledge Synthesis	Licensed Database
11	Lower Extremity	Ankle	Randomized Clinical Trial	Licensed Database
12	Lower Extremity	Hip	Randomized Clinical Trial	Alternate
13	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
14	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
15	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
16	Lower Extremity	Mixed lower extremity	Randomized Clinical Trial	Licensed Database
17	Lower Extremity	Ankle	Randomized Clinical Trial	Alternate
18	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database

Citation #	Region	Subregion	Study Design	Retrieval Route
19	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
20	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
21	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
22	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
23	Lower Extremity	Hip	Randomized Clinical Trial	Alternate
24	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
25	Lower Extremity	Hip	Randomized Clinical Trial	Alternate
26	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
27	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
28	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
29	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
30	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
31	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
32	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
33	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
34	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
35	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
36	Lower Extremity	Hip	Randomized Clinical Trial	Alternate
48	Lower Extremity	Mixed lower extremity	Controlled Clinical Trial (Concurrent control)	Licensed Database
49	Lower Extremity	Ankle	Controlled Clinical Trial (Concurrent control)	Alternate
50	Lower Extremity	Ankle	Controlled Clinical Trial (Concurrent control)	Licensed Database
51	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database
52	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database
53	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database
54	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database
55	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database
56	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database
57	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database
58	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database
59	Lower Extremity	Knee (Patella)	Controlled Clinical Trial (Concurrent control)	Licensed Database
60	Lower Extremity	Ankle	Controlled Clinical Trial (Historical control)	Licensed Database
61	Lower Extremity	Hip	Controlled Clinical Trial (Historical control)	Alternate

Citation #	Region	Subregion	Study Design	Retrieval Route
62	Lower Extremity	Hip	Controlled Clinical Trial (Historical control)	Alternate
63	Lower Extremity	Hip	Controlled Clinical Trial (Historical control)	Licensed Database
65	Lower Extremity	Hip	Longitudinal Cohort	Licensed Database
66	Lower Extremity	Hip	Longitudinal Cohort	Licensed Database
67	Lower Extremity	Hip	Longitudinal Cohort	Alternate
68	Lower Extremity	Hip	Longitudinal Cohort	Alternate
69	Lower Extremity	Hip	Longitudinal Cohort	Licensed Database
70	Lower Extremity	Hip	Longitudinal Cohort	Licensed Database
71	Lower Extremity	Hip	Case_Control	Licensed Database
72	Lower Extremity	Hip	Case_Control	Alternate
73	Lower Extremity	Hip	Single Subject Design	Licensed Database
74	Upper Extremity	Proximal Humeral	Knowledge Synthesis	Licensed Database
75	Upper Extremity	Distal Radial	Knowledge Synthesis	Alternate
76	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
77	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
78	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
79	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
80	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
81	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
82	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
83	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
84	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
85	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
86	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
87	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
88	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
89	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
90	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
91	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
92	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
93	Upper Extremity	Distal Radial	Randomized Clinical Trial	Licensed Database
94	Upper Extremity	Mixed, Upper Extremity	Randomized Clinical Trial	Licensed Database
95	Upper Extremity	Proximal Humeral	Randomized Clinical Trial	Licensed Database
96	Upper Extremity	Proximal Humeral	Randomized Clinical Trial	Licensed Database
97	Upper Extremity	Proximal Humeral	Randomized Clinical Trial	Licensed Database
98	Upper Extremity	Proximal Humeral	Randomized Clinical Trial	Alternate
99	Upper Extremity	Proximal Humeral	Randomized Clinical Trial	Alternate
100	Upper Extremity	Radial Headl	Randomized Clinical Trial	Alternate

Citation #	Region	Subregion	Study Design	Retrieval Route
103	Upper Extremity	Distal Radial	Controlled Clinical Trial (Concurrent control)	Alternate
104	Upper Extremity	Distal Radial	Controlled Clinical Trial (Concurrent control)	Licensed Database
105	Upper Extremity	Distal Radial	Controlled Clinical Trial (Concurrent control)	Licensed Database
106	Upper Extremity	Mixed, Upper Extremity	Controlled Clinical Trial (Concurrent control)	Licensed Database
107	Upper Extremity	Distal Radial	Theses, Abstract summary	Licensed Database
108	Vertebral	Vertebral	Randomized Clinical Trial	Licensed Database
109	Vertebral	Vertebral	Randomized Clinical Trial	Alternate
110	Vertebral	Vertebral	Randomized Clinical Trial	Licensed Database
111	Vertebral	Vertebral	Randomized Clinical Trial	Licensed Database
112	Vertebral	Vertebral	Randomized Clinical Trial	Licensed Database
113	Vertebral	Vertebral	Randomized Clinical Trial	Licensed Database
114	Vertebral	Vertebral	Controlled Clinical Trial (Concurrent control)	Licensed Database
115	Vertebral	Vertebral	Longitudinal Cohort	Licensed Database
116	Mixed Regions	Mixed, any fracture, older adults	Knowledge Synthesis	Licensed Database
117	Mixed Regions	Mixed, Hip (n=2) and Vertebral (n=6)	Randomized Clinical Trial	Licensed Database
118	Mixed Regions	Mixed, Any Op Fracture, not defined	Controlled Clinical Trial (Concurrent control)	Licensed Database
119	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
101_1	Upper Extremity	Distal Radial	Randomized Clinical Trial	Alternate
101_2	Upper Extremity	Distal Radial	Randomized Clinical Trial	Alternate
102_1	Upper Extremity	Proximal Humeral	Randomized Clinical Trial	Alternate
102_2	Upper Extremity	Proximal Humeral	Randomized Clinical Trial	Alternate
37_1	Lower Extremity	Hip	Randomized Clinical Trial	Alternate
37_2	Lower Extremity	Hip	Randomized Clinical Trial	Alternate
38_1	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
38_2	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
39_1	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
39_2	Lower Extremity	Hip	Randomized Clinical Trial	Alternate
40_1	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
40_2	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
41_1	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
41_2	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
42_1	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
42_2	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
43_1	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
43_2	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database

Citation #	Region	Subregion	Study Design	Retrieval Route
44_1	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
44_2	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
45_1	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
45_2	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
46_1	Lower Extremity	Mixed lower extremity	Randomized Clinical Trial	Licensed Database
46_2	Lower Extremity	Mixed lower extremity	Randomized Clinical Trial	Licensed Database
46_3	Lower Extremity	Mixed lower extremity	Randomized Clinical Trial	Licensed Database
47_1	Lower Extremity	Hip	Randomized Clinical Trial	Licensed Database
47_2	Lower Extremity	Hip	Randomized Clinical Trial	Alternate
64_1	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database
64_2	Lower Extremity	Hip	Controlled Clinical Trial (Concurrent control)	Licensed Database

Gaps in the literature

Notable gaps in the literature related to exercise prescription following fracture in older adults include:

- A limited number of studies and no knowledge synthesis related to early or late exercise prescription following vertebral fracture.
- Poor delineation of the efficacy or effectiveness of early post-fracture mobilization strategies following upper extremity fractures treated either conservatively or surgically.
- Inconsistent or incomplete details of specific exercise prescription characteristics in the lower extremity fracture literature.

Future research directions

Three key areas for focused knowledge synthesis were identified and are currently underway by the OSTEO-FX team (see Acknowledgments for details of the OSTEO-FX team).

The primary research questions being addressed in these ongoing syntheses are:

- Does therapeutic exercise prescription, alone or as an adjunct to other rehabilitation interventions, decrease pain, increase strength, enhance quality of life and/or decrease re-fracture rates in people over 45 who have sustained one or more clinically diagnosed vertebral fractures compared to no or different therapeutic exercise prescriptions?
- Does early post-fracture active mobilization improve the quality and rate of physical functional recovery in people over 45 who have sustained an upper extremity fracture compared to immobilization or standard care?
- What elements of exercise prescription following lower extremity fracture in older adults are associated with improved quality and rate of fracture healing and functional recovery and/or reduced secondary fracture, mortality and direct health care costs: A Bayesian analyses?

Figure 1. Scoping Study Overview. A systematic literature search and mapping strategy informed by iterative research-user collaborations.

Figure 2.

Study Flow Chart. A flow chart of the literature retrieval, review, selection and initial sorting by study design and body region. NOTE: Numbers in { } represent the citations progressing through the initial screening and inclusion/exclusion process. Numbers in () represent the final 134 citations included, whereas, numbers in [] represent the final 119 unique studies identified.

Figure 3. Citation Mapping. An overview of the distribution of unique studies sorted by study design and approximate timing of intervention (< or > 12 weeks) across fracture body region(s).

Figure 4. Primary Health Outcomes. Trends for health outcome domain for the primary outcome measures reported in each body region [RCT and CCT studies (n=95)].

Table 1

Primary and secondary health outcomes (not exhaustive)

	Healing/bone health	Functioning	Prevention	Cost/burden
Primary	Time to 'union'	Self-reported functioning test score	Secondary fall rate	Length of stay in hospital(s)
	Final fracture alignment (mal-union)	Functional performance test score	Secondary fracture rate	Number of visits
Secondary	Nonunion	Strength	Mortality	Time off work/sport
	Secondary fracture reduction	Joint range of motion	Change in living status	Direct medical/care costs
	Post-fracture analgesics	Flexibility	Functional decline/dependency	Indirect 'other' medical or socio-economic costs
	Post-fracture antibiotics	Coordination		Impact/burden on caregiver
	Other post-fracture medications	Balance		
	Secondary 'fracture-related' wound care	Aerobic capacity		
	Secondary 'fracture-related' admission and/or surgery	Ambulation		
	Bone density/bone mineral density	Pain		
		Self-efficacy/fear/mood		
		Cognition		

Table 2

Electronic information sources

* Licensed Database Sources/Access Timelines	
•	MEDLINE (via OvidSP, 1950 to 3 July 2009);
•	MEDLINE In-Process and other non-indexed citations (via OvidSP 1950 to 3 July 2009);
•	EMBASE (via OvidSP, 1980 to 3 July 2009);
•	CINAHL (via EBSCOhost, 1982 to 3 July 2009);
•	EVIDENCE MEDICINE REVIEWS: (via OvidSP October 2008 to 3 July 2009)
–	CENTRAL
–	Cochrane Database of Systematic Reviews
–	DARE
** Gray Literature Sources:	
•	PEDro Physiotherapy Evidence Database http://www.pedro.org.au/
•	OT Seeker Occupational Therapy Systematic Evaluation of Evidence http://www.otseeker.com/default.aspx Canadian Physiotherapy Association http://www.physiotherapy.ca/public/public.asp OCLC FirstSearch http://firstserch.oclc.org
•	Agency for Healthcare Research and Quality (AHRQ) http://effectivehealthcare.ahrq.gov
•	CERTs Research: Women's Health http://www.ahrq.gov/clinic/certswomen.htm#ref3
•	Canadian Task Force on Preventive Health Care http://www.ctfphc.org/Tables/Osteo_tab.htm
•	Canadian Medical Association guidelines http://www.sogc.org/guidelines/public/159E-JPS-May2005.pdf
•	Canadian Consensus Conference on Osteoporosis, 2006 Update http://www.sogc.org/guidelines/public/172E-CONS-February2006.pdf Health Technology Assessment http://www.hta.ac.uk
•	National Library of Guidelines Specialist Library. National Library for Health (UK)
•	*** National Library for Health http://www.library.nhs.uk
•	Scottish Intercollegiate Guidelines Network http://www.sign.ac.uk/guidelines/html Clinicaltrials.gov http://clinicaltrials.gov
•	Bandolier http://www.medicine.ox.ac.uk/bandolier/
•	National Rehabilitation Information Center (NARIC) http://www.naric.com ProQuest theses and dissertations http://proquest.umi.com
•	World Health Organization Health Evidence Network http://www.euro.who.int/HEN
•	Google http://www.google.ca
•	Google Scholar http://scholar.google.ca/

* Specific search strategies available on request

** All electronic gray literature sources were routinely re-searched throughout the duration of this study with a final search cutoff date of July 3, 2009.

*** Renamed Health Information Resources, April 1, 2010.

Table 3
Exercise program components and sub-categories of exercise prescription characteristics

Exercise prescription characteristics	Exercise program components	Sub-categories/examples (not exhaustive)
Time post-fracture	Number of weeks post-fracture	Immediate (0–3 weeks), delayed (4–12 weeks), intermediate (13–26 weeks), or late (>26 weeks)
Person prescribing	Health professional prescribing exercise	Physical therapist, occupational therapist, physician/surgeon, nurse, kinesiologist, athletic therapist, multi-disciplinary
	Specialized training of person(s) prescribing	Geriatrics, exercise physiology, sports medicine, orthopedics, other
	Program design	Individualized or standardized/care pathway
Program structure	Setting or location	Inpatient (acute/rehabilitation), outpatient clinic, home-based (independent-living/assisted-living), or community-based
	Method of instruction	Individual sessions, group sessions, written, video, web-based
	Degree of supervision	Ongoing supervision, intermittent supervision, no supervision
	Regional fracture (structural impairment) focus	Range of motion, strengthening, stretching/flexibility, posture
Level of functioning (ICF) focus	Physical performance (activity limitation) focus	Walking, transfer activities, stairs, dressing, personal hygiene, lifting/carrying, balance, coordination/dexterity/agility
	Physical activity (restricted participation) focus	Swimming, aerobics, yoga/Tai Chi/Pilates, sport/music/work
	Frequency/duration	Number sessions/week, number minutes/session, program duration (weeks), total number of visits
	Intensity	Number of repetitions/repetitions maximum, heart/respiration rate, accelerometer/pedometer
Exercise script parameters	Progression	Individualized, standardized/pre-defined, self-directed, no progression
	Adherence	Daily log/diary, recall (interview/questionnaire), 24-hour monitoring
	Other non-exercise therapeutic intervention(s)	Education, manual therapy, electro-physical agents
	Other non-therapeutic interventions	Diet, medications, counseling, caregiver support
Co-interventions		

ICF = International Classification of Functioning, Disability and Health

Table 4

Knowledge synthesis literature related to exercise prescription in older adults after fracture: Study objectives, populations included, key practice and research findings/recommendations.

Region	Citation	Research purpose/objective	Population(s) included	'Exercise prescription' evidence-informed findings/recommendations	Recommendations for future research
Mixed regions	Cameron et al (2000) [74] Systematic review	To identify evidence for the effectiveness and cost-effectiveness of programs of care following the acute management of fractures in older people.	Older (> 65 years) people with fractures in the lower limbs, pelvis, upper limbs or spine. Primary focus on hip fractures.	Insufficient data to assess the impact of any rehabilitation program on level of function, morbidity, quality of life or impact on caregivers.	A standardized outcome data set should include assessment of: <ul style="list-style-type: none"> • function, • health-related quality of life, • caregiver burden, • economic analysis
Hip	* Cameron et al (2001) [75] Cochrane review	To examine the effects of coordinated, multidisciplinary, inpatient rehabilitation compared with usual (orthopedic) care, for older patients with hip fracture.	Older patients with any type of fracture of the proximal femur which had been surgically fixed.	No conclusive evidence of the effectiveness of coordinated post-surgical care typified by the Geriatric Orthopedic Rehabilitation Unit model following proximal femoral fracture; there is a trend towards effectiveness in all main outcomes.	Research evaluating the effectiveness of specialized inpatient rehabilitation should include: <ul style="list-style-type: none"> • functional status • direct and indirect costs, cost-effectiveness • caregiver burden Components of the rehabilitation interventions used in trials should be carefully specified.
Hip	**Chilov et al (2003) [76] Systematic review	To develop updated, evidence-based guidelines for the treatment of proximal femoral fractures to optimize functional outcome while minimizing length of stay in hospital.	Subjects aged > 50 years, and proximal hip fractures not related to metastatic disease or multiple trauma.	<u>Mobilization:</u> <ul style="list-style-type: none"> • early assisted ambulation should begin within 48 hours postoperatively (Level III) • no particular mobilization strategies can be recommended over others (Level II). <u>Rehabilitation:</u> <ul style="list-style-type: none"> • A coordinated rehabilitation program should be available to patients with hip fracture, commencing early after hospital admission, and should provide opportunities for early supported discharge for patients who can manage this. (Level II) 	None stated

Region	Citation	Research purpose/objective	Population(s) included	'Exercise prescription' evidence-informed findings/recommendations	Recommendations for future research
				<ul style="list-style-type: none"> For more frail patients, a coordinated inpatient rehabilitation program should be provided that is followed by a period of continuing rehabilitation after discharge. (Level II) 	
Hip	Beaupre et al (2005) [77] Practice guideline	To determine evidence-based best practices for elderly hip fracture patients from the time of hospital admission to 6 months post fracture	65+ years, hip fracture patients	No clear Level 1 evidence exists that multidisciplinary care with early mobilization affords better outcomes in terms of mortality, morbidity, function, or service utilization than usual care.	The hypothesis that standardization of care (rehabilitation) would be expected to streamline practice and improve the quality of care ought to be tested. Investigation as to type and extent of rehabilitation is needed in sub-acute settings (e.g., long-term care, regional hospitals, homecare)
Hip	Toussant & Kohia (2005) [78] Systematic review	To combine relevant research regarding the most appropriate PT intervention for the treatment of hip fractures.	Over age 60, with hip fracture treated surgically.	<p>It is difficult to isolate the role of PT from that of other care received after hip fracture.</p> <p><u>Grade A recommendation:</u></p> <ul style="list-style-type: none"> Patients with mild or moderate dementia will benefit from a multidisciplinary rehabilitation team to regain function. <p><u>Grade B recommendations:</u></p> <ul style="list-style-type: none"> Treadmill gait training can be used to improve mobility outcomes. A home-based rehabilitation program is as good as hospital rehabilitation for patients who had not lost many functional abilities prior to hip fracture. Elderly persons are commonly "detrained" so a PT program should be continued even after pre-fracture status has been attained. 	<p>Future research needs to:</p> <ul style="list-style-type: none"> attempt to isolate PT from other disciplines. provide an operational definition of functional recovery after hip fracture (mobility and assessment of activities of daily living before and after fracture).
Hip	Halbert et al (2007) [79] Systematic review	To determine from randomized controlled trials, the effectiveness of multidisciplinary rehabilitation in comparison with usual orthopedic care following hip fracture.	Patients aged > 50 years, following hip fracture.	<p><u>Return to home:</u></p> <ul style="list-style-type: none"> A trend towards increased returning home following multidisciplinary rehabilitation; with the modest size of this result, a possible reflection of the increasingly multi- 	<p>Research needs standardized outcome measures in:</p> <ul style="list-style-type: none"> health services measures such as length of hospital stay, functional measures including activities of

Region	Citation	Research purpose/objective	Population(s) included	'Exercise prescription' evidence-informed findings/recommendations	Recommendations for future research
				<p>disciplinary approach of routine orthopedic care.</p> <p><u>Physical functioning:</u></p> <ul style="list-style-type: none"> No differences between intervention and control groups, with no data analyses (two trials). No statistically significant differences between the groups (two trials). Intervention group did better than the controls; however, it was not possible to pool the data (five trials). 	<p>daily living and mobility.</p>
Hip	Handoll et al (2007) [80]	To evaluate the effects of different mobilization strategies after hip fracture surgery in adults on: mobility and function; mortality and complications; resources; acceptability of and adherence to interventions.	Skeletally mature patients treated for a hip fracture at any stage during rehabilitation.	<p>There is insufficient evidence from randomized trials to establish the effectiveness of the various mobilization strategies used in rehabilitation after hip fracture surgery.<u>Early/immediate in-patient mobilization:</u></p> <ul style="list-style-type: none"> no significant differences in unfavorable outcomes for weight bearing started at 2 versus 12 weeks after internal fixation of a displaced intracapsular fracture (one historic trial). comparison of more intensive with less intensive regimen of PT: one trial found no difference in recovery, the other found a higher level of drop-outs in the more intensive group with no difference in length of hospital stay (two trials). short-term improvement in mobility and balance for a two-week program of weight-bearing versus non-weight-bearing exercise (one trial). improved mobility in those given a quadriceps muscle strengthening exercise program (one trial). no significant difference in recovery of mobility after a treadmill versus conventional 	<p>Further primary research should focus on:</p> <ul style="list-style-type: none"> interventions likely to have a beneficial, overall, long-term impact follow up of validated and patient-orientated outcome measures economic outcomes additional provision of optimal format and resource implications of intensive supervised exercises, primarily aimed at enhancing mobility <p>Debatable whether research priorities should be on the evaluation of multi-faceted or multi-component interventions with mobilization components, rather than mobilization interventions or programs by themselves.</p> <p>It is still useful to investigate mobilization strategies in themselves, as these will form a substantive part of any rehabilitation intervention.</p>

Region	Citation	Research purpose/objective	Population(s) included	'Exercise prescription' evidence-informed findings/recommendations	Recommendations for future research
				<p>gait retraining program (one trial).</p> <p><u>Post-discharge mobilization:</u></p> <ul style="list-style-type: none"> Continuation of therapy immediately after discharge from hospital involving 12 weeks of intensive physical training (one trial) and a home-based PT program (one trial) improved outcomes. Extension of therapy after completion of standard post-discharge PT found improved outcome after 6 months of intensive physical training (one trial) whereas another trial found no significant effects of home-based resistance or aerobic training (one trial). PT introduced later. One trial found improved outcome after home-based exercises started around 22 weeks from injury. One trial found home-based weight-bearing exercises starting at 7 months produced no statistically significant differences aside from greater quadriceps strength. 	
Hip	Chudyk et al (2009) [81] Practice guideline	To conduct a critical examination of the literature in the area of rehabilitation after hip fracture; to identify practices that have strong evidentiary bases as well as areas needing further research.	50+ years, with hip fracture	<p><u>Improved ambulatory ability was associated with:</u></p> <ul style="list-style-type: none"> <i>In-patient (acute) setting:</i> high-frequency PT and OT in an acute inpatient setting In-patient (rehabilitation) <i>setting:</i> combined PT and OT care, treadmill gait retraining, PT plus quadriceps training, weight-bearing exercise. <i>Outpatient setting:</i> combined aerobic and progressive resistance training, combined strength and functional training, and a home care rehabilitation setting 	<p>Measures and methods for characterizing interventions and settings were not well standardized. Defining standard measures of key outcomes or measures is needed. Usual care conditions need to be described in terms of components (intensity, duration, timing). Research needs conceptual/theoretical frameworks.</p>

Region	Citation	Research purpose/objective	Population(s) included	'Exercise prescription' evidence-informed findings/recommendations	Recommendations for future research
				<p><u>Improved functional ability was associated with:</u></p> <ul style="list-style-type: none"> <i>In-patient (acute) setting:</i> intensive OT and/or PT exercises, early mobilization, high-frequency OT/PT and additional OT combined with PT <i>In-patient (rehabilitation) setting:</i> combined PT and OT care and combined aerobic and progressive resistance training <i>Outpatient setting:</i> combined aerobic and progressive resistance training, combined strength and functional training, and a home care rehabilitation setting. <p><u>Improved lower extremity strength was associated with:</u></p> <ul style="list-style-type: none"> <i>In-patient (rehabilitation) setting:</i> combined PT and OT care <i>Outpatient setting:</i> combined aerobic and progressive resistance training, weight bearing and progressive resisted exercises and/or aerobic exercises. 	
Hip	SIGN (Scottish Intercollegiate Guidelines Network) (2009) [82] Practice guideline	To ensure that older people with hip fracture receive optimal management.	Older people with hip fracture.	<p>Grade B recommendations Rehabilitation:</p> <ul style="list-style-type: none"> A multidisciplinary team should be used to facilitate the rehabilitation process. <p><u>Rehabilitation: early assessment.</u></p> <ul style="list-style-type: none"> Early, corroborated history, multidiscipline (medical, nurse, PT, OT) to formulate rehabilitation and discharge plan. Should include pre-morbid function and mobility, available social support, current relevant clinical conditions and mental status. Patients with comorbidities, poor functional ability and low 	<p>The following areas for further research:</p> <ul style="list-style-type: none"> effectiveness and cost-effectiveness of discharge planning and rehabilitation after hip fracture. interventions to reduce further fragility fractures. follow up and rehabilitation of patients.

Region	Citation	Research purpose/objective	Population(s) included	'Exercise prescription' evidence-informed findings/recommendations	Recommendations for future research
				mental status pre-fracture should undergo rehabilitation in a geriatric orthopedic rehabilitation unit.	
Ankle	Smith et al (2006) [83] Systematic review	To evaluate whether postoperative ankle mobilization exercises improve outcome following open reduction and internal fixation of ankle fractures compared to immobilization.	People treated with open reduction and internal fixation of ankle fractures (any age, gender or duration of follow up)	Early postoperative ankle exercises may not necessarily improve ankle function in the long term, but may provide some early benefit in range of movement, functional ankle scores and pain compared to immobilization.	Future research should be undertaken to rectify methodological design limitations, applying larger, well-controlled randomized trials, with a suitable follow-up period.
Ankle	Lin et al (2008) [84] Cochrane review	To compare the effectiveness of different rehabilitation interventions following ankle fracture in adults.	Adult participants presenting to a hospital or community setting for rehabilitation following ankle fracture treated with either conservative or surgical orthopedic management.	<p>Rehabilitation during period of immobilization after surgical fixation:</p> <ul style="list-style-type: none"> • use of a removable type of immobilization combined with exercise reduced activity limitation. • using no immobilization, early commencement of weight-bearing, or using a removable type of immobilization combined with exercise showed a positive effect on ankle range of motion. <p>Rehabilitation during the period of immobilization after conservative management:</p> <ul style="list-style-type: none"> • very little evidence is available. <p>Rehabilitation after immobilization after conservative management:</p> <ul style="list-style-type: none"> • manual therapy may improve ankle range of motion. • no evidence of an effect for stretching 	<p>Priority following surgical management investigating effects of:</p> <ul style="list-style-type: none"> • exercise and weight-bearing if started during the period of immobilization, • exercise after the period of immobilization. <p>Defining the best management of people after conservative orthopedic management needs to be established.</p>
Proximal humerus	Handoll et al (2003) [85] Cochrane review	To examine the evidence for the effects (benefits and harms) of different treatments, including rehabilitation, interventions in skeletally mature adults with fractures of the proximal humerus.	Patients who had completed skeletal growth, with a fracture of the proximal humerus. Stratification by age (under versus over 65 years) if possible.	<ul style="list-style-type: none"> • Some good-quality albeit limited evidence that early PT, without routine immobilization, is effective for undisplaced two part fractures. • Limited evidence that short periods of arm immobilization are acceptable and, that given adequate instruction, some patients may manage their own rehabilitation program with 	There is a need to determine if a simple, un-displaced fracture should be immobilized, and if so, for how long, and the timing, type and extent of PT required.

Region	Citation	Research purpose/objective	Population(s) included	'Exercise prescription' evidence-informed findings/recommendations	Recommendations for future research
Distal radius	Handoll et al (2008) [86] Cochrane review	To examine the evidence for the effects (benefits and harms) of rehabilitation interventions in adults with conservatively or surgically treated distal radius fractures.	Patients of either sex who have completed skeletal growth and who are receiving treatment for a fracture of the distal radius.	<p>careful selection and longer term monitoring.</p> <p>Insufficient evidence from randomized trials to determine how best to manage the rehabilitation of adults with fractures of the distal radius. It is not possible to establish exactly what rehabilitation intervention is necessary for acceptable functional recovery, or what type of rehabilitation specialists should provide this care, or when or for how long this care should be provided, or in what circumstances it should be provided. <u>Early Rehabilitation:</u></p> <ul style="list-style-type: none"> Weak evidence of improved hand function after early hand therapy or OT in the days after plaster cast removal, with some beneficial effects continuing one month later (two trials). No evidence of differences in outcome between supervised and unsupervised exercises (one trial). <p><u>Post-immobilization rehabilitation:</u></p> <ul style="list-style-type: none"> Weak evidence of a lack of clinically significant differences in outcome in patients receiving formal rehabilitation therapy (four trials) or passive mobilization (two trials). Weak evidence of better short-term hand function in participants given PT compared to home exercises by a surgeon (one trial). 	<p>Priorities:</p> <ul style="list-style-type: none"> examination of the provision, mode and format of advice and instruction for home exercises both during the definitive treatment period and post-immobilization. potential differences in impact of rehabilitation in different participant groups and circumstances. evidence for rehabilitation after surgery
<p>ADDITIONAL COMMENTS: Related Updates or New Publications subsequent to July 3, 2009</p> <p>Updated Citations:</p> <p>* This version was withdrawn in October 2009 and replaced with: Handoll HH, Cameron ID, Mak JC, Finnegan TP. Multidisciplinary rehabilitation for older people with hip fractures. <i>Cochrane Database Syst Rev.</i> 2009 Oct 7;(4):CD007125. Review</p> <p>** Previous publication: March LM, Chamberlain AC, Cameron ID, et al. How best to fix a broken hip. <i>Fractured Neck of Femur Health Outcomes Project Team. Med J Aust.</i> 1999;170: 489-494. Updated Version (2010): Mak JC, Cameron ID, March LM; National Health and Medical Research Council. Evidence-based guidelines for the management of hip fractures in older persons: an update. <i>Med J Aust.</i> 2010 Jan 4;192(1):37-41.</p> <p>New Citation:</p> <p>Bachmann S, Finger C, Huss A, Egger M, Stuck AE, Clough-Gorr KM. Inpatient rehabilitation specifically designed for geriatric patients: systematic review and meta-analysis of randomized controlled trials. <i>BMJ.</i> 2010;340:c1718</p>					

OT = occupational therapy. PT = physical therapy