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Maximising functional recovery following hip fracture in frail seniors

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Abstract

This review discusses factors affecting recovery following hip fracture in frail older people as well as interventions associated with improved functional recovery. Prefracture function, cognitive status, co-morbidities, depression, nutrition and social support impact recovery and may interact to affect post-fracture outcome. There is mounting evidence that exercise is beneficial following hip fracture with higher-intensity/duration programmes showing more promising outcomes. Pharmacologic management for osteoporosis has benefits in preventing further fractures, and interest is growing in pharmacologic treatments for post-fracture loss of muscle mass and strength. A growing body of evidence suggests that sub-populations – those with cognitive impairment, residing in nursing homes or males – also benefit from rehabilitation after hip fracture. Optimal

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Conflict of interest statement

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post-fracture care may entail the use of multiple interventions; however, more work is needed to determine optimal exercise components, duration and intensity as well as exploring the impact of multimodal interventions that combine exercise, pharmacology, nutrition and other interventions.

Keywords

Hip fracture; Exercise; Rehabilitation; Frailty; Cognitive impairment; Pharmacological management

Introduction

Hip fracture represents a global public health issue with 1.6 million hip fractures reported worldwide in 2000 [1]. Loss of function is common after hip fracture and many patients who survive are unable to return to independent community living [2–4]. Ongoing long-term care costs when patients are unable to return to the community are one of the largest components of the total costs associated with the ongoing care of hip fracture patients [5].

Increasing age is accompanied by loss of bone and muscle mass [6–8], and increases the risk of falls leading to fracture [9]. Hip fractures most commonly occur in the older population, following a simple fall from standing height in the presence of osteoporosis; 70% occur in women [10]. In addition, many patients with hip fracture present with multiple concomitant medical issues that can adversely affect recovery [2,11].

There are also sub-populations of patients who may be at a risk of poor functional recovery after hip fracture, may require different treatments and therefore require special consideration. These include patients with pre-existing functional [12,13] and cognitive [14] limitations, those residing in nursing homes or other permanent long-term care settings at the time of hip fracture [15–17] and men [18–20].

Pharmacologic management for osteoporosis has been shown to be an effective secondary prevention strategy in reducing the risk of subsequent fractures [21]. Exercise also appears to be beneficial following hip fracture, although some findings are as yet equivocal and more evidence is needed to determine optimal components, timing, intensity and duration [22]. Areas of treatment currently under exploration are treatment of sarcopenia, the use of different modes of exercise, nutritional supplementation and pharmacologic management. Only limited attention has been given to multimodal interventions that consider these interventions as potentially complementary treatment strategies.

This chapter will discuss pre-existing factors that affect recovery following hip fracture as well as interventions that have been shown to restore functioning and independence after a hip fracture. Gaps in current knowledge will be outlined with directions for future research.

Prefracture factors affecting functional recovery

There is good evidence that patients' health status at the time of hip fracture has an impact on recovery. 'Reduced prefracture functional independence' has consistently been shown to adversely affect recovery following hip fracture [12,13]. Those patients who are more limited in daily activities or ambulation at the time of their fracture are more likely to experience more significant functional loss in the first year after hip fracture than those who were independent in daily activities and ambulation. For example, in a cohort analysis of 571 subjects, Eastwood et al. [14] reported that of those who were independent in locomotion prior to fracture, 10% were dependent in locomotion within 6 months of fracture. By contrast, of those who required assistance with locomotion prior to hip fracture, 31% were dependent in locomotion at 6 months after fracture.

'Co-morbid conditions', common in the medically compromised hip fracture patient population [23], delay or reduce recovery and may lead to increased medical care and costs [11,14]. Leibson et al. [2] reported that 45% of hip fracture patients had a Charlson Comorbidity Index >1 compared to 30% of matched controls, and multiple studies have demonstrated that those with a greater co-morbid disease burden at the time of fracture do more poorly in the years following the fracture [14,24].

One of the most common pre-existing conditions is 'cognitive impairment', with which approximately 42% (95% confidence intervals (CI) 37, 46%) of the hip fracture population will present [25]. People with dementia have higher odds of falling than those without cognitive impairment [26]; thus, people with cognitive impairment or dementia have a higher risk of hip fracture. In turn, recovery after hip fracture has been shown to be negatively impacted by the presence of cognitive impairment. Morgen et al. [27] reported that at 1 year after hip fracture, subjects without cognitive impairment needed little supervision to walk, whereas 50% of subjects with impaired cognition required human assistance to walk. Further, 25% of cognitively impaired subjects also required assistance in transfers and self-care while almost all of the subjects without cognitive impairment had returned to full independence in those tasks [28].

Affective status or 'depression' can adversely affect recovery after hip fracture as well [29,30]. Depression can augment behavioural symptoms of cognitive impairment [31] and may affect the capacity to participate in rehabilitation [30]. For example, even after adjustment for covariates and potential confounders, patients with moderate to severe depressive symptoms were more likely to not be able to walk independently at hospital discharge (odds ratio (OR) 3.2; 95% CI 1.3, 7.8) and to be institutionalised or die by a year after their fracture [30]. Conversely, positive affect can lead to improved recovery after hip fracture. Fredman et al. [29] reported that at 6 months, even after risk adjustment, those with a positive affect had a mean usual walking pace of 0.06 m s^{-1} faster than those with depressive symptoms.

'Poor nutritional status', which is associated with increased mortality after hip fracture, may also negatively impact functional recovery [32]. In a multivariate analysis in one study, poor nutritional status at the time of fracture was associated with lower odds of walking independently 6 months after hip fracture (OR 0.77, 95% CI 0.66, 0.90) [33].

The role of 'social support' is another factor that affects recovery following hip fracture. Subjects with good social support systems are more likely to return to independent living arrangements than those with poor social support [34]. Shuyu et al. [35] reported that those subjects who had family members who sought further information on both caregiving and related health-care needs were more likely to recover their walking ability than those who did not.

All of these aforementioned factors often interact and coalesce under the concept of frailty. 'Frailty' is a term and concept that is widely applied clinically. There is general agreement that it is a state associated with impaired homoeostatic mechanisms that predisposes older people to unfavourable health and social outcomes [36]. Hip fracture is a consequence of impaired homoeostasis with reference to maintaining an upright posture and therefore many older people with hip fracture meet the definitions of frailty.

An understanding of frailty is useful in programmes that aim to restore functioning and independence in a person following a hip fracture because it suggests that there are multiple factors to be addressed. These can be identified systematically using the well-established techniques of geriatric evaluation and management [37]. Through this process, it may be feasible to identify intervention targets, for example, previously undiagnosed cognitive impairment, in addition to instituting multi-component programmes that aim to improve functioning broadly [38].

The presence of frailty is starting to guide treatment for some health conditions because it has been shown that frailty can predict response to treatment and likelihood of adverse complications [39]. The extent of frailty has also been shown to be associated with outcome in people with hip fracture [40], but to our knowledge, this information has not been used to guide treatment and rehabilitation approaches.

Functional recovery after hip fracture

Functional recovery appears to follow a sequence that may inform an approach for patient management to maximise recovery. Magaziner et al. [3] reported that patterns of recovery vary by functional domain with depression, cognitive function and upper extremity activities of daily living (ADLs) reaching maximum recovery within 4 months of fracture, while balance and gait can take up to 9 months after fracture to recover. Instrumental and physical ADLs are slower to recover, if indeed, subjects are able to regain these higher levels of function, and may take up to 1 year following fracture. These findings align with the process of disablement proposed by Verbrugge and Jette [41] and may have implications for determining appropriate interventions and timing of interventions to promote maximal recovery.

What do we know about restoring function and independence?

Following hip fracture, the early perioperative recovery period focusses on establishing medical stability and commencing early mobilisation strategies to prevent common postoperative complications. Multidisciplinary care that includes medical, rehabilitative and nursing interventions is recommended during this early recovery phase [42]. However, recovery after hip fracture continues throughout the first postoperative year and beyond, and more consideration should be given to post-acute management after the acute hip fracture episode to maximise functional recovery and return to the highest level of independence possible. Treatment strategies during this phase include exercise interventions as well as secondary prevention of future fractures through pharmacologic management of osteoporosis.

Benefits of exercise

There is now strong evidence that well-designed exercise and physical training interventions can enhance muscle strength [43] and balance [44] and prevent falls [45] in older people. There is also mounting evidence [22] that exercise and physical training can enhance recovery of function and independence in older people after hip fracture. However, optimal intervention programmes to maximise post-hip fracture functioning are yet to be established. Thus, although most current hip fracture guidelines indicate the need for rehabilitation, they do not outline key components of rehabilitation programmes that should be delivered [46]. As many of the trials in this area are small and inconclusive, they do not provide clear evidence to guide practice and, as a result, the conclusions of the relevant Cochrane review are that there is "*insufficient evidence from randomised trials to establish the best strategies for enhancing mobility after hip fracture surgery*." [22].

Despite limitations of prior studies, an inspection of the exercise components of interventions in trials that demonstrated enhanced physical functioning after hip fracture provides useful information. Interventions that used a higher dose of exercise tended to show stronger effects on important outcomes [22]. Examples of programmes found to be effective in individual trials are discussed below and the findings of randomised trials testing these programmes are summarised in Table 1.

More intensive physiotherapy followed by a home programme has shown positive outcomes after hip fracture. Bischoff-Ferrari et al. [47] compared extended physiotherapy (60 min per day during acute care plus an unsupervised home programme after discharge) with standard physiotherapy (30 min per day during acute care without a home programme). Individuals receiving the more intensive programme had a 25% lower rate of falls in the 12 months after hospital discharge compared to those in the control group.

Intensive outpatient centre-based rehabilitation has been found to enhance recovery after hip fracture in several trials. Binder and colleagues [48] compared 6 months of supervised physical therapy and exercise training with home exercise and found significantly better physical performance, functional status, muscle strength, walking speed, balance and perceived health in the more intensive group. The exercise intervention sessions lasted for 45–90 min and were conducted three times a week. Control participants were instructed to complete a home-based programme of flexibility exercises three times a week. Similarly, Hauer et al. [49] found 12 weeks of progressive resistance and functional training three times a week to improve strength and functional motor performance and balance and reduced fall-related behavioural and emotional problems when compared to placebo motor activities such as seated calisthenics, games and memory tasks undertaken three times a week for 1 h.

Several studies have found particular types of exercises to be beneficial. Progressive resistance training has been found to be safe and effective in people after hip fracture when delivered in inpatient [50] or outpatient settings [51–55] or as a supervised home programme [56]. Outcomes that have been improved by progressive resistance training have included muscle strength, gait speed, endurance, overall physical functioning and self-reported health.

It may also be possible to enhance physical functioning without resistance training. Exercises undertaken in upright positions (i.e., standing and walking) have been found to have greater impacts on functional recovery than more passive seated or bed exercises in inpatient rehabilitation [57] as well as in home-based situations [58]. There is an indication of ‘specificity of exercise’ in these results.

A number of trials have demonstrated important improvements from interventions started after the completion of usual care [48,49,51,52,54–56,59]. This suggests that the exercise interventions delivered as a part of usual care are not generally of sufficient intensity and/or duration to maximise recovery. This appears to be the case even in more affluent countries with generally good health-care systems. It is likely that the deficit between the extent of hip fracture that can be achieved and the level of recovery that is generally achieved is even greater in resource-poor settings.

Exercise is probably even more effective if delivered as part of a multidisciplinary rehabilitation programme. A trial by Singh et al. [53] found a reduced risk of death and nursing home admission, better ADL performance and less assistive device use after 12 months of high-intensity progressive resistance training with the targeted addition of multidisciplinary treatment of frailty.

We have summarised trials of exercise interventions found to improve physical functioning after hip fracture. There have been a number of other trials that have not demonstrated the effects of exercise. Many had small sample sizes, so they possibly lacked the statistical power to detect effects. However, one relatively large trial [60] (n = 180) failed to find an impact on the physical functioning of home-based aerobic and resistive exercise delivered by an exercise trainer although the intervention group showed increased overall physical activity. This finding indicates the need for further large-scale trials to investigate key components and optimal intervention doses and delivery methods. The more effective interventions seem to involve visits to specialised outpatient clinics and higher intensity of exercise. This intensive form of exercise programme may not be acceptable to some older people and their caregivers and will be more expensive to deliver on an ongoing basis to the millions of people suffering hip fractures across the globe each year. Further studies need to investigate costs and effects of different exercise programmes as well as investigate participant views of exercise. The global challenge for hip fracture research and clinical practice is how to deliver high-dose mixed interventions in a manner that is cost effective and acceptable to participants, their families, providers and payers.

Secondary prevention through pharmacologic management for bone health

Hip fractures are well recognised as a consequence of bone fragility, which is caused by decreased bone mass. Low bone mineral density (BMD) is common in older persons and is a risk factor for hip fracture [9]; on average, BMD at the hip declines 0.5–1% per year among elderly women who have not fractured a hip [8]. By contrast, the decline in BMD is 4–7% in the year following hip fracture [61,62], contributing to the higher risk of subsequent fractures in these patients [63]. Additionally, hip fractures are associated with an 8.4–36% excess mortality within the year following the fracture [64].

Treatment options for osteoporosis encompass lifestyle modification including vitamin D supplementation and adequate calcium intake, weight-bearing exercise, smoking cessation and reduction in alcohol intake as well as prescription medications. The two major categories of pharmacologic treatment of osteoporosis are: (1) antiresorptive and (2) anabolic medications. Antiresorptive medications include alendronate, risendronate, ibandronate, zoledronic acid, calcitonin, oestrogen agonist/antagonist, oestrogens and/or hormone therapy, raloxifene, denosumab and strontium ranelate. Teriparatide is the only anabolic medication approved for the treatment of osteoporosis.

The detection and treatment of osteoporosis has been found to be cost effective and showed lower mortality in both women and men [65]. Only zoledronic acid has been tested and approved by the Food and Drug Administration (FDA) and other regulatory bodies for use in hip fracture patients after showing benefits in reducing subsequent fractures, increasing BMD and reducing mortality [21].

New guidelines advise that pharmacologic therapy should not be considered indefinite in duration, and there is limited evidence of efficacy beyond 5 years [66]. There should be a comprehensive risk assessment after the initial 3- to 5-year treatment period. Despite these recommendations and the proven benefits of the medications, most hip fracture patients do not receive definitive pharmacologic treatment, nor is osteoporosis evaluation generally performed [67,68]. Osteoporosis diagnosis, which increases the likelihood of treatment [67], is made in <20% of women who sustain a hip fracture, even after the event [67,68]. General treatment rates under 20% are typical, even as long as 1 year after the fracture [67–69], and less aggressive vitamin D supplementation with or without calcium is the most commonly used treatment [69].

What are clinical areas that require further attention for improving function and independence after a hip fracture?

Greater attention to muscle weakness may promote better recovery after hip fracture, but further work is required to delineate effective interventions. In addition, there are sub-populations of patients who, until recently, have been routinely overlooked in the published literature. Subjects with preexisting cognitive impairment have been systematically excluded from many studies of hip fracture rehabilitation [70], and evidence is sparse regarding the impact of rehabilitation on those with cognitive impairment who reside in permanent residential settings at the time of hip fracture [71]. Finally, most studies of hip fracture have focussed on females, who make up 70% of the population. Although less is known about the recovery of male hip fracture patients, a growing body of evidence supports that they also benefit from rehabilitation [18–20,24].

Improving muscle mass and performance

The progressive loss of muscle mass with ageing has been associated with decreasing physiologic and functional reserve [72], and accelerated or greater losses may indicate the development of sar-copenia [73,74]. Although there is lack of agreement on the rate of muscle loss with ageing, the most commonly reported rate is <1% year over age 50 [75]. Recent reports from the Health Aging Body Composition (HABC) study suggest that in the eighth decade of life, men lose 0.8–0.98% of their lean mass per year while women lose 0.64–0.70% per year [6,7]. Janssen et al. [76] also reported that in a cohort of 200 women and 268 men, the rate of muscle loss in the lower extremity was double that of the upper extremity. This is especially critical for hip fracture patients, in whom gait and balance are affected by the fracture. Fox et al. [62] also documented a 6% decline in lean body mass at 12 months post fracture in a sample of elderly female hip fracture patients; fat mass increased by 4–11% over the same time period [62,77]. Accelerated losses of muscle mass and strength after hip fracture may contribute to future fracture risk and to slower recovery of function. A number of modifiable factors can contribute to the observed reductions in muscle mass and strength. These include physical inactivity, a reduction in endogenous anabolic hormone concentrations (e.g., sex steroids, growth hormone and insulin-like growth factor) [78], poor nutrition, vitamin D deficiency [79] and disease processes such as arthritis.

To our knowledge, only two pilot studies of anabolic therapy have been performed with hip fracture patients. Sloan et al. [80] randomised 29 elderly female hip fracture patients undergoing inpatient postoperative rehabilitation to receive intramuscular nandrolone (2 mg kg q weekly) for 4 weeks or until hospital discharge. They did not observe group differences in the changes in measures of body composition, grip strength, ADL recovery or hospital length of stay. The study, however, had significant limitations. The treatment period was relatively short. The only measure of strength was handgrip dynamometry, relatively insensitive measures of body composition were used (skinfold thickness, mid-arm circumference and bioelectric impedance) and nutritional intake and steroid hormone levels were not controlled. Nandrolone was relatively well tolerated, and there were no group differences in adverse events. Van der Lely et al. [81] conducted a randomised controlled trial (RCT) of 6 weeks of human growth hormone (hGH) in 111 hip fracture patients (mean age 78.5 ± 9.1 years). Patients were randomised within 24 h of hip fracture. There were differences in the changes in the Modified Barthel Index between treatment groups. In a subgroup analysis among patients older than 75 years, the proportion of patients returning to their prefracture living situation was higher among those on hGH. Both these studies were limited by their small sample size and the limited measurements obtained.

Myostatin is a member of the transforming growth factor beta superfamily that is a potent suppressor of muscle growth, development and regeneration. Inhibition of myostatin can induce muscle hypertrophy, and in a mouse injury model, blocking myostatin signalling improved fracture healing and enhanced muscle regeneration [82]. Studies of myostatin inhibitors in older adults with muscle weakness are ongoing, and if proven beneficial, future studies in hip fracture patients are planned.

Another Cochrane review concluded that there is some evidence for the effectiveness of protein and energy supplementation after hip fracture [83]; however, this review focussed more on mortality and complications rather than functional recovery after hip fracture. Evidence is mixed as to the impact of nutritional supplementation on recovery of function after fracture [32,33,84]; further work is needed to determine the impact of post-fracture nutritional supplementation on functional recovery. This is particularly important as multimodal treatment approaches that include exercise, nutritional and/or pharmaceutical in combination are further explored.

Sub-populations of patients who experience hip fracture

Almost 50% of the hip fracture patient population have a diagnosis of dementia or test positive on a cognitive function battery immediately after the fracture event [25]. Two other notable sub-populations are those admitted from residential settings (e.g., nursing homes), who represent up to 25% of all hip fractures [16], and males who represent approximately 30% of all hip fractures [19,23].

Impaired Cognition: Hip fracture is more common in those with cognitive impairment [26]. Further, those with cognitive impairment are less likely to regain prefracture level of function and more frequently require permanent residential care [14]. However, a growing body of evidence suggests that patients with cognitive impairment may experience similar relative gains in function following post-fracture rehabilitation to those without cognition difficulties. Two recent systematic reviews reported that relative outcomes did not significantly differ among those with and without cognitive impairment who receive rehabilitation, suggesting that subjects with cognitive impairment benefitted from exposure to rehabilitation [71,85]. Allen et al. [71] reported on 13 studies that looked at both institutionally based and home-based rehabilitation following hip fracture for those with cognitive impairment, while Muir et al. [85] focussed only on institutionally based rehabilitation programmes that included subjects with cognitive impairment. Unfortunately, most studies included in these reviews were non-randomised and were heterogeneous in terms of the proportion of participants with cognitive impairment, as well as degree of cognitive impairment. Further, descriptions of interventions were lacking and the timing of assessment and choice of outcomes/outcome measures varied considerably; thus, no meta-analyses were possible. Despite this heterogeneity, most studies reported that relative gains in function were similar among those with and without cognitive impairment.

Four RCTs have been performed to date that included community-dwelling subjects with cognitive impairment who received intensive inpatient rehabilitation compared to those who received the usual postoperative care (Table 2). Huusko et al. [86] compared inpatient geriatric rehabilitation to usual care where subjects were discharged to local hospitals. In their sample, 132 had cognitive impairment that spanned the spectrum of mild ($n = 68$) to severe dementia ($n = 28$). At the end of the first year following the fracture, more patients with mild to moderate dementia in the intervention group returned to independent living compared to those who received the usual postoperative care. In subgroup analyses, Naglie et al. [4] and Moseley et al. [87] found that patients with mild to moderate cognitive impairment experienced more benefit from higher-intensity interventions than those without cognitive impairment. Moseley et al. [87] reported that those with cognitive impairment showed significant improvements in several outcomes at 4 and 16 weeks after the higher-intensity intervention including improved walking speed and function, and reduced pain compared to those without cognitive impairment who performed the lower-intensity intervention. Naglie et al. [4] also found that fewer subjects who received intensive inpatient rehabilitation after hip fracture showed a decline in ambulation or transfers and more had returned to their prefracture residence at 6 months than those with cognitive impairment who received the usual postoperative care. Vidan et al. [88] reported that although those without cognitive impairment reported higher levels of function following rehabilitation than those with cognitive impairment, both groups had significant functional gains.

Stenvall and colleagues [89] reported on a subgroup of 64 subjects with moderate to severe dementia who were either community dwelling or residing in a permanent residential setting at the time of hip fracture. Their study compared an intensive multidisciplinary intervention on a geriatric ward to usual hospital care on an orthopaedic ward. Postoperative complications were significantly reduced in the intervention group compared to usual care. Despite randomisation, there was disparity between the groups in prefracture independence in ambulation – only six participants in the intervention group walked independently prior to fracture compared to 17 in the usual care group ($p = 0.03$). At 4 months post fracture, more participants in the intervention group retained independent ambulation compared to the usual care group ($p = 0.005$). Further, at 1 year post fracture, more subjects in the intervention group had regained their prefracture activity than the control group ($p = 0.03$).

Residential Care: As the most common reason for requiring institutional care is the presence of dementia, this group represents a further subgroup with cognitive impairment who often have concomitant frailty. Limited descriptive studies suggest that this group experienced the poorest recovery following hip fracture [15–17] . In two different prospective cohort studies of subjects who were residing in nursing homes at the time of their fracture, a substantial proportion of subjects who were ambulating prior to their hip fracture were either dependent in ambulation or non-ambulatory within 6 months of hip fracture [16,90].

In the study by Stenvall et al. [89], approximately 76% of those with cognitive impairment were admitted from nursing home settings, adding evidence that this frailest group is still able to achieve benefits from rehabilitation following hip fracture. Uy et al. [91] attempted an RCT that focussed entirely on the residential population and compared intensive inpatient rehabilitation to usual care; however, they were forced to halt their study when changes within their health-care system prevented the trial from being completed.

Despite the lack of evidence for rehabilitation in these frail elders, rehabilitation staff who work in long-term residential settings report similar rehabilitation goals of returning patients to prefracture functional levels [92]. Further, a qualitative study examining the perception of a rehabilitation outreach programme for nursing home patients indicated that the programme was positively received by nursing home staff; both outreach rehabilitation and nursing home staff reported benefits to the patients’ recovery following hip fracture [93].

Male patients: Although men represent approximately 30% of the hip fracture population, their outcomes have been less frequently studied than that of women. Several studies have suggested that men are younger, sicker and more likely to die following hip fracture [14,19,20,23,24,94]. However, evidence is more limited when comparing functional recovery following hip fracture between men and women. In three studies of almost 4500 participants that examined functional recovery at 6 months or 1 year following hip fracture, there were no differences in function between male and female survivors [19,24,94]. Endo also reported no difference in the rate of institutionalisation at 1 year [94].

In studies of earlier follow-up (30–60 days post hip fracture), findings have been more heterogeneous. Dimonaco et al. [95] (*n* = 1094 participants; 124 males) and Semel et al. [96] (*n* = 557 participants; 133 males) reported that men had lower function at discharge from rehabilitation than women, while Arinzen et al. [18] (2010) (*n* = 99; 35 males) reported that men had better function at discharge. Lieberman et al. [20] (*n* = 808; 194 males) reported no difference in function at 30 days between men and women. Further work is needed to determine if men and women follow different trajectories of recovery following hip fracture.

Looking to the future: what areas require further investigation?

To date, interventions for improving outcomes from hip fracture have typically focussed on one intervention mode at a time with the possible addition in more recent studies of vitamin D and calcium given their increased use in general practice for osteoporosis and fall prevention. Future research is needed on combined or multimodal interventions that simultaneously or sequentially address different deficits in this complex patient group. We need evidence as to whether exercise will benefit from the addition of protein or a muscle-enhancing agent.

Future research also needs to continue addressing the reasons for suboptimal recovery with the understanding that designing effective interventions beyond the surgical fixation are compounded by the co-morbid diseases and disabilities that patients have at the time of their fracture. Recognising that hip fracture is as much a geriatric problem as it is an orthopaedic one, attention is being given to orthogeriatric programmes and extended care pathways to provide guidance on how best to care for these frail patients with multiple morbidities and functional deficits. Programmes and pathways are starting to emerge in many regional and national health-care systems to treat and manage this costly problem in a complex patient group [97,98]. These are very positive developments and provide new opportunities for improving outcomes from hip fracture. Still, the evidence, while expanding, is still limited as to what should be delivered and when to deliver it in these care systems [99].

To fill the gaps in knowledge and to design multimodal interventions for diverse groups of fracture patients will require a large and organised effort. One approach for accomplishing this will be to assemble networks of investigators and clinical sites that are committed to collaborating towards the conduct of these observational and mechanistic studies and the development and rapid testing of promising interventions. These networks would have the benefits of not only shared knowledge but also the ability to mount studies with large numbers of patients quickly and efficiently. As systems of care delivery recognise the consequences of hip fracture and begin to pay more attention to improving outcomes and reducing their care costs, there is a need to develop interventions and rapidly evaluate their efficacy and cost effectiveness so they can be implemented in emerging care delivery systems.

Summary

A great deal is known about many of the functional and physiologic consequences of hip fracture, and about factors that interfere with optimal recovery. Yet, there is still a considerable amount to be learnt about the deficits that follow hip fracture and the reasons why some individuals and patient subgroups recover and others do not. Definitive, evidence-based strategies for treating and managing the many observed deficits in physical, cognitive and affective function, and the losses in bone and muscle, in those who have hip fractures are lacking. The future will require continued investigation of the consequences of hip fracture, as well as the development and testing of individual and combined treatment strategies. Studies of the underlying mechanisms for observed losses and for restoration of specific functions may give clues to the interventions likely to be most beneficial. More research also is needed to determine if sub-populations of hip fracture patients can experience improved recovery through improved access to rehabilitation. Prospective studies are needed to determine if the sequelae of hip fractures reported to date apply equally to men, those with cognitive limitations and those in long-term residential care settings, and if distinct, consideration should be given to including these groups in randomised clinical trials of pharmacologic and rehabilitation intervention studies.

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Practice points

- Physical therapy and/or activity should be provided during the acute care stay and for an extended period after discharge. This should likely include progressive strength training exercises and other strategies to address the individual deficits that are identified.
- Pharmacologic management of osteoporosis is an effective secondary prevention treatment strategy.
- Post-fracture care should include ensuring adequate vitamin D3 and calcium intake.
- Patients residing in long-term residential care facilities and those with cognitive impairment should be considered for inclusion in rehabilitation programmes after hip fracture.

Research agenda

- Multimodal interventions should be evaluated in future clinical trials to determine the benefits of combining exercise, nutrition, pharmacologic and other management strategies.
- More evidence is required to understand the best post-fracture rehabilitation strategies for male hip fracture patients and patients with cognitive impairment, depression and for those who reside in permanent residential settings.
- Further work is required to determine evidence-based treatment parameters for exercise programmes - intensity, post fracture for delivery time, duration and content.
- Additional study of specific post-fracture losses and specific strategies for addressing each is needed.
- Further study is needed of the underlying mechanisms for observed post-fracture losses and for restoration of specific functions.
- The role of muscle loss, sarcopenia and nutrition on recovery following hip fracture requires further research, as does the role of physical and pharmacologic approaches in managing these deficits.
- Further study of the role that co-morbid disease and frailty play in the recovery process is needed in order to inform orthogeriatric care.

Table 1

Trials showing benefits from exercise programs after hip fracture.

Author, date, Country	Interventions	Results	Sample size	PEDro scale [100] quality score
Interventions started in the inpatient setting				
Bischoff-Ferrari et al., 2010 [47]; Switzerland	Comparison of extended physiotherapy (PT) (supervised 60 min/day during acute care plus an unsupervised home program) versus standard PT (supervised 30 min/day during acute care plus no home program; single-blinded). All patients also received cholecalciferol. The PT interventions were provided for approximately 7 days.	• Extended versus standard PT reduced the rate of falls by 25% (95% CI −44%, —1%) but had no effect on hospital readmissions.	173	6/10
Sherrington et al., 2003 [57]; Australia	Comparison of either weight-bearing (*n*=40) ornon-weight-bearing (*n* = 40) exercise prescribed by a physiotherapist. Both interventions were conducted on a daily basis for 2 weeks.	• Both groups improved markedly (in the order of 50%) on measures of physical ability however there was no significant difference between the groups in the extent of improvement. • Additional strength benefits were found for the non-weight-bearing group and additional functional benefits were found for the weight-bearing group who also needed less supportive walking aids ($p = 0.045$).	80	7/10
Mitchell et al., 2001 [50]; Scotland	Randomised controlled trial comparing the addition of 6 weeks quadriceps training (training; *n* = 40 patients) with standard PT alone (control; *n* = 40 patients). The training group exercised twice weekly for 6 weeks, with 6 sets of 12 repetitions of knee extension (both legs), progressing up to 80% of their one-repetition maximum.	• Leg extensor power increased significantly in the training group compared with the control group. Significant benefits were maintained at 16 weeks. • Quadriceps training resulted in a greater increase in elderly mobility scale score compared with standard rehabilitation (between-group difference of 2.5 (95% CI 1.1, 3.8) at week 6 and 1.9 (0.4, 3.4) at week 16). • Barthel score increased significantly from week 0–6 in the training group compared with controls (Mann-Whitney *U*-test $p = 0.05$). • Patients in the training group scored significantly better in the energy sub-score of the Nottingham Health Profile at the end of follow-up (Mann- Whitney U-test $p = 0.0185$).	80	5/10
Trials started after discharge from hospital or at the end of usual care				
Sylliaas et al., 2012 [55]; Norway	The intervention group (*n* = 48) underwent a 3 month progressive strength training program with one session at an outpatient clinic and another session at home. The control group (*n* = 47) was asked to maintain their current lifestyle.	• There were no statistically significant differences between groups in the primary outcome Berg Balance Scale. • The intervention group showed significant improvements in strength, gait speed and gait distance, instrumental activities of daily living and self-rated health.	95	8/10

Author, date, Country	Interventions	Results	Sample size	PEDro scale [100] quality score
Sylliaas et al., 2011 [54]; Norway	The intervention group (n = 100) received a 3-month strength training program conducted by a physiotherapist twice a week with a home session to be completed once per week. The control group was asked to maintain their current lifestyle.	• At follow-up, the intervention group showed highly significant improvements both in the primary endpoint (Berg Balance Scale, mean difference 4.7 points) and in secondary end- points of sit-to-stand, 6 min walk test, gait speed, step height, timed up and go and instrumental activities of daily living.	150	8/10
Mangione et al., 2010 [56], USa	Exercise and control participants received interventions by physical therapists twice weekly for 10 weeks. The exercise group received high intensity leg strengthening exercises. The control group received transcutaneous electrical nerve stimulation and mental imagery.	• Isometric force production (p < 0.01), usual and fast gait speed (p= 0.02 & 0.03, respectively), 6 min walk distance (p < 0.01), and modified physical performance test (p < 0.01) improved at one year post fracture with exercise. • Effect sizes were 0.79 for strength, 0.81 for modified physical performance test scores, 0.56 for gait speed, 0.49 for 6 min walk, and 0.30 for SF-36 scores.	26	7/10
Portegijs et al., 2008 [52]; Finland	12 week intensive progressive strength-power training program twice a week for 1–1.5 h (n = 24) Control group (n = 22) encouraged to maintain their pre-study level of physical activity during the 12-week trial.	• Asymmetric leg extension power deficit decreased (p= 0.010) after training compared with the control group. • Leg extension power of the stronger leg, asymmetric knee extension strength deficit, walking speed, and balance performance were not significantly affected by training. • Self-reported ability to walk outdoors improved after training.	46	6/10
Mard et al., 2008 [51]; Norway	The intervention group (n = 23) underwent a 12-week supervised and progressive muscle strength and power training program twice a week. The control group (n = 20) was encouraged to maintain their pre-study level of physical activity during the 12-week trial.	• 14 subjects in the training group and only 2 controls felt that their mobility had improved during the intervention period (p= 0.002). • Training had no significant effect on TUG, chair rise and stair climbing time and walking time.	43	7/10
Sherrington et al., 2004 [59]; Australia	Compared the effectsofweight-bearing (n = 40) and non-weight-bearing (n = 40) home exercise programs and a control program (n = 40). 5 and 8 exercises were prescribed to be carried out daily for a period of 4 months.	• At the 4-month retest, there were between-group differences compared to the initial assessment for the measures of balance and functional performance but not for strength or gait. • The weight-bearing exercise group showed the greatest improvements in measures of balance and functional performance (between-group differences of 30%-40% of initial values).	120	7/10
Binder et al., 2004 [48]; USA	Participants were randomly assigned to 6 months of supervised PT and progressive resistance exercise training (n = 46) or home exercise control (n = 44). The exercise	• PT participants had improved physical performance and less self-reported disability than control participants at the final follow-up evaluation.	90	7/10

Author, date, Country	Interventions	Results	Sample size	PEDro scale [100] quality score
	intervention sessions lasted for 45–90 min and were conducted 3 times per week. Control participants were instructed to complete their home program of flexibility exercises 3 times per week also.	• Changes over time in the Physical Performance Test (PPT) and Functional Status Questionnaire (FSQ) scores favoured the PT group (*p*= 0.003 and *p*= 0.01, respectively). • PT also had significantly greater improvements than the control condition in measures of muscle strength, walking speed, balance, and perceived health but not bone mineral density or fat-free mass.		
Hauer et al., 2002 [49]; Germany	Intervention group (*n* = 15) performed progressive resistance and functional training to improve strength and functional performance 3 days a week for 12 weeks. Control group (*n* = 13) met 3 times a week for 1 h and engaged in placebo motor activities such as seated calisthenics, games and memory tasks.	• Training significantly increased strength, functional motor performance and balance and reduced fall-related behavioural and emotional problems. • Some improvements in strength persisted during 3-months follow-up while other strength variables and functional performances were lost after cessation of training. • Patients in the control group showed no change in strength, functional performance and emotional state during intervention and follow-up.	28	6/10

Table 2

Randomised trials of rehabilitation after hip fracture that included subjects with cognitive impairment.

Author, date, country,	Intervention	Results	Sample size (*n* (%) with cognitive impairment)
Huusko et al., 2010 [86]; Finland	Inpatient geriatric rehabilitation (intervention) provided on a geriatric ward by a multi-disciplinary team with PT 2 times/day and a focus on early mobility and self-care vs. usual post-operative care (control)	• 1 year after hip fracture, 91% of subjects in the intervention group with mild to moderate dementia had returned to living in the community compared to only 63% of the control group. • Median length of stay was 47 days for intervention subjects with moderate dementia (n= 24) compared to 147 days in control subjects (n= 12); p= 0.04.	243 (132 (54%))
Moseley et al., 2009 [87]; Australia	Inpatient rehabilitation that included either weight-bearing exercises twice daily for a total of 60 min/day for 16 weeks (HIGH intervention) or exercises in sitting once daily for 30 min/day for 4 weeks (LOW intervention).	• 4 and 16 weeks after fracture, those with cognitive impairment who received the HIGH intervention reported improved walking speed (4 week mean difference = 0.20 m/s; 95% CI 0.07, 0.340; 16 week mean difference = 0.24 m/s; 95% CI 0.05–0.440); improved function as measured by the Barthel Index (4 week mean difference = 9; 95% CI 17, 35; 16 week mean difference = 17; 95% CI 6, 27) compared to those without cognitive impairment who received the LOW intervention. • 16 weeks after fracture, those with cognitive impairment who received the HIGH intervention also reported improved outcomes on the Falls Efficacy Scale (p= 0.009) and the EQ-5D (p= 0.034), were more likely to walk without aids (p= 0.018), and have no or only slight pain (p= 0.024) than those without cognitive impairment who received the LOW intervention.	160 (54 (34%))
Naglie et al., 2002 [4]; Canada	Inpatient interdisciplinary care (intervention) that included prevention strategies for common issues (delirium, urinary problems, constipation, pressure ulcers, poly pharmacy), early mobilisation and PT 2 times/day, and early discharge planning vs. usual post-operative care (control)	• 17/36 (47%) of the intervention group and 9/38 (24%) of the control group were alive with no decline in ambulation, transfers or change in residential status at 6 months (p= 0.03).	280 (74 (26%))
Stenvall et al., 2012 [89];Sweden	Multidisciplinary program (intervention) that included prevention of postoperative complications (e.g. pressure ulcers, delirium, falls), nutritional assessment, comprehensive pain management and early mobilisation with daily physical therapy throughout the hospital stay compared to usual care (control)	• Fall incidence was significantly lower among patients with dementia in the intervention group compared to the control group (1 (4%) vs. 11 (31%); p= 0.008). • 4/6 (67%) in the intervention group regained independent walking status at 4 months compared to 1/17 (6%) (p = 0.005) • 10/19 (53%) in the intervention group regained pre-fracture functional independence compared to 8/26 (21%) (p= 0.027)	199 (64 (32%))