



Hip Flexor and Knee Extensor Muscle Strength Characteristics of Community-Dwelling Women with Recent Hip Fractures: A Case Study of Extent of Persistent Inter and Intra-limb Strength Assymetries

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Abstract

Objectives: To examine the profile of hip flexor and knee extensor strength measures among other factors in the context of recovery from an acute hip fracture among a sample of six community dwelling otherwise healthy women.

Methods: Records of the hip flexor and knee extensor strength of six women with right-sided hip fractures followed up for six months were analyzed.

Results: All women presented with interlimb strength assymetries at all stages of their rehabilitation program, as well as intralimb differences in recovery rates between the hip and knee muscles. While strength improved in most cases, this was not consistent within or across subjects, and was significant between 6 weeks and 6 months only for the uninjured side ($p < 0.05$). Those with better hip flexor symmetry strength scores at six months had more rapid Get Up and Go scores, ($p = .008$), number of walking laps completed was higher ($p = .049$). Hip flexor muscle strength on the uninjured side at 6 months independently predicted the subject's ability to rise from a chair as rapidly as possible, and knee strength on the uninjured side predicted walking distance ($p < .05$).

Conclusion: Hip flexor and knee extensor strength deficits of the affected leg are still evident among community dwelling hip fracture cases at six months, regardless of whether subjects take part in intensive exercise interventions or not. The presence of hip flexor and knee extensor strength deficiencies and assymetries from side to side which prevail for an extended period after surgical repair influences overall functional ability at 6 months. **Implications:** Improving leg strength after hip fracture surgery requires careful baseline and ongoing periodic evaluations and tailored prolonged interventions to avert the increased risk of falling and sustaining second hip fractures associated with suboptimal muscle strength of the legs. Optimally reducing interlimb and intralimb discrepancies in hip flexor and knee extensor muscle strength can be expected to improve functional ability.

Keywords: Fractures; Hip flexors muscles; Hip fracture; Knee extensor muscles; Rehabilitation; Strength

Introduction

Prevailing literature detailing hip fractures and their outcomes continues to support the highly negative impact of this injury on individual health, and personal independence [1-4]. In particular, if the leg muscles remain weak after hip fracture surgery, one can strongly anticipate suboptimal functional recovery rates, plus higher healthcare utilization and costs [5], despite vast improvements in recent surgical strategies for treating this serious clinical condition. In addition, the presence of poor or suboptimal recovery of lower limb strength, might also explain why some hip fracture patients are more prone to post-surgical complications than others who undergo similar surgery for other conditions, such as hip arthritis. Weaker patients may also be a greater risk for catastrophic declines in outdoor walking ability [6,7], plus secondary falls than those with enhanced muscle strength who can perform muscle-loading activities such as climbing stairs [4-8]. Moreover, if muscle strength is not symmetrically distributed from side to side, balance as well as function could be compromised [9]. Conversely, those patients who are less prone to further injury after hip fracture surgery and recover independence may be those able to generate muscles forces sufficient to elicit protective reflexes in a timely way, regardless of perturbations that can cause falls and the later development of secondary hip osteoarthritis.

However, early investigations of strength recovery rates even among healthy robust patients, showed significant differences between the injured and non-injured sides on discharge [9,10], and because hip fractures occur in the elderly, who already may be weak, plus the fact hip surgery entails cutting of nerves to the hip, the recovery rate

of muscles at the hip and possibly the knee may be impeded in their recovery to some degree by related factors such as pain, or muscle atrophy [7]. Further, there may be a gain in regional muscle fat content in addition to a muscle mass loss post-surgery [11]. As well, due simply to soft tissue and muscular trauma, and its immediate consequences, a patient who has sustained a hip fracture may have reduced leg strength that is greater than that due to ageing [12-14], and may exhibit chronic inflammation [15], and/or thigh edema [16]. They may also present with signs of poor muscle coordination [17], impaired sensorimotor function of their leg muscles [18], and excessive weakness if they have comorbidities, such as hip osteoarthritis [19]. As indicated by Kristenson et al. [20], a post-operative rehabilitation program which does not account for the unique effects trauma, disease and surgery may have on an individual patients overall leg strength, may consequently fail to promote optimal functional outcomes for an individual patient as alluded to by Munin et al. [21] and Sherrington and Lord [22].

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Hip fractures are one of the most serious health care problems facing aging nations, and those who survive this injury may experience permanent institutionalization, premature death, high morbidity rates, and an associated increase in risk of a second fracture [23,24]. Some degree of this increased morbidity appears due to the fact recovery rates of muscle strength may not be uniform in all hip fracture cases [25-27], there may be unanticipated muscle mass losses [28] and persistent pain [29] that increases the tendency towards weakness. The present case series was designed to examine the potential value of careful evaluation of muscle strength capacity at baseline and during the recovery period in key muscles of the lower leg on both sides, regardless of injury side. It was also designed to highlight the possible need for more extensive or targeted and tailored rehabilitation strategies which focus on facilitating optimal strength recovery of both the hip flexors and the knee extensors in both the short-term and long-term post fracture periods, as well as balance. While previously studied in the context of the knee extensor muscles to some degree, recovery rates of muscle strength at the hip, and related changes at the knee have not been studied extensively in the related literature with respect to community dwelling women who are in good general health and have sustained fractures on their dominant side as a result of falls.

Objectives

Based on a review of the literature and the research questions under consideration, this case study specifically attempted to examine if:

1. Hip fracture patients either receiving intensive exercise therapy or not receiving therapy experience prolonged muscle imbalances from side to side with respect to the hip flexor and knee extensor muscles.
2. Hip flexor and knee extensor muscle strength assymetries are predictive of functional outcomes at six months.
3. If leg strength imbalances from side to side are influenced by age, body mass, whether the individual was receiving exercise instruction or not, or whether they had a cervical fracture or an inter trochanteric fracture.

Methodology

The strength records of six adult females with right sided hip fractures who underwent surgical fixation were reviewed at 6 weeks, 3 months, and 6 months after surgery for the affected leg as well as the unaffected leg. The non-normalized strength values, as well as ratios of leg strength of the affected hip flexors and knee extensors with respect to the hip flexors and knee extensors of the affected and unaffected legs were computed. The six subjects selected were those who had experienced an acute hip fractures preceded by a fall, were otherwise healthy, and had agreed to be followed progressively to examine their hip and knee strength profiles over a six month post-operative period. The strength testing protocol was conducted in a standard manner by experienced tester in the seated position using a hand held strength testing device and a one repetition maximum test with free weights placed at the ankle to assess maximal force capacity of the hip flexors and knee extensors of both legs to the nearest kilogram. The participants had to be free of cancer, cardiovascular, and neuromuscular diseases as determined by their medical histories, ambulatory, with or without aids, and living in the community. In addition to strength measures, age, height, weight, and body mass index measures, reason for hip fractures, timed Get Up and Go tests involving asking the patient to stand up from a chair as fast as they could, Functional Reach scores, recorded by asking subjects to stand and reach forward as far as possible

with their upper limbs and recording the distance, and number of laps recorded on a six minute self-paced walking test on an indoor walkway were examined. The initial and final strength scores for both limbs were scanned to examine if the resultant imbalance was uniformly due to weakness on the affected side.

The specific dependent variables chosen for analysis were:

1. The cohorts non-normalized uncorrected hip flexor and knee extensor strength scores of the injured leg relative and uninjured leg as assessed bilaterally at 6 weeks, 3 months, and 6 months in response to the one repetition maximum test.
2. An asymmetry score, whereby the fractured leg strength score for each muscle group was compared to the combined strength score of both legs and symmetry or no asymmetrical was taken as a value of 50% according to Portegijs et al. [30]. Lower values indicated an asymmetrical deficit, and poorer strength in the affected leg.
3. Strength change scores for each leg for each muscle group of each individual over time.
4. Average time to stand up on three occasions as quickly as possible from a seated position, number of laps recorded during a six minute walk test, and number of centimeters recorded on a functional reach test.

All subjects had been referred to the study by surgeons and decisions regarding subject suitability for the study were made by the investigator. All subjects had provided informed consent. Those who exercised did so for 2-3 times a week for eight weeks using free weights, according to 60 percent of their one-repetition maximum tested at each exercise session for each muscle of each leg. In addition, the knee flexors and hip extensors of both legs were exercised in sitting and standing with varied forms of resistance designed to increase leg strength.

Once collected, the data were then entered into a computerized database and analysed using descriptive and inferential statistics. The statistical package SPSS version 17 for a personal computer was used to examine the extent of selected relationships and differences which existed among the data, using standardized t-tests, and bivariate correlations. Factors evaluated as independent predictors of outcome included age, gender, type of fracture, reason for fracture, use of vitamin D supplementation, body mass indices, body weight and height. Significance was set at $p=0.05$.

Results

The key characteristics of the sample are presented in Table 1. All were relatively healthy community dwelling adults, with no osteoporosis history, or current fractures at other sites, and all were on vitamin D supplementation. Five of the six had inter-trochanteric fractures and all had fallen prior to fracturing their hips. None were complaining of pain which had decreased more than 70 percent from baseline in all cases by the end of the six month period using a subjective pain scale. Four had been actively participating in a hospital based tailored eight week exercise program designed to strengthen the leg muscles and improve their balance, while two had been following a home exercise routine. All were right handed with right sided fractures.

In terms of strength recovery, there was evidence of greater weakness on the uninjured side in two separate cases for the hip flexor muscles and knee extensor muscles, respectively. Only one subject

	Mean	S.D.	Min	Max
Age (yr)	77.8	8.5	68	92
Weight (kg)	57.0	7.6	45.4	63.5
Height (m)	1.6	0.1	1.37	1.68
BMI (kg/m ²)	22.3	3.1	18.00	26.00

Table 1: Descriptive characteristics of the six initially acute hip fracture cohorts as assessed at baseline 6 weeks after surgery.

exhibited symmetry between the two muscle groups from side to side, in this case for the hip flexors.

The overall trends in strength for the hip flexors and knee extensors are shown in Figures 1 and 2. The resultant asymmetry that existed on average between the affected and unaffected sides, regardless of whether this was an injured or uninjured side is shown in Table 2 for the two muscles studied. As depicted these were not uniform over time, and between the muscle groups. The value reached in the case of the hip flexors and knee extensors suggests muscle strength in these two groups were clearly not equal from side to side at six months.

In terms of correlations between the measures of strength across time for the hip flexors, Table 3 shows these tended to improve over the study period, but did not approach unity in all cases. This was similar for the knee extensor muscles but there was diminishing concordance for this muscle group over time.

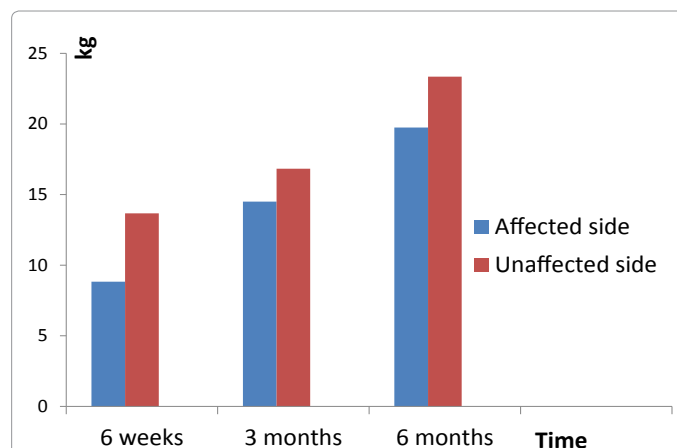
Table 4, depicting the intra-limb strength relationships for the affected and the unaffected side, shows these were generally more concordant on the non-fracture side over time. In terms of correlations between the functional variables, only the extent of hip symmetry at six months predicted speed on the Get Up and Go Sit to Stand test ($r=-.96$, $p=.008$) and number of laps completed on a six minute walk test ($r=.88$; $p=.049$). Neither age, nor body mass index, nor whether the patient exercises or not, appeared to influence the functional outcomes or hip asymmetry scores, and knee asymmetry scores were not related to the functional measures in any way. Strength of the uninjured hip flexors and knee extensors at baseline were not correlated with walking distance, functional reach or standing up from a chair as quickly as possible. Hip flexor strength of the uninjured side at six months showed a positive trend as far as getting up from a chair as rapidly as possible goes ($r=-.85$; $p=.065$). Knee strength of the uninjured leg showed a positive trend as far as number of walking laps completed were concerned ($r=.95$; $p=.075$). Although the injured limb generally displayed greater weakness than the uninjured limb for both muscles, studied, this was not uniformly the case.

Discussion

This study series involved generally healthy older women 66-85 years of age, who had fractured their hips as a result of a fall and were living in the community. They were assessed at different points in time with respect to their maximal hip flexor and knee extensor strength capacity, as well as body weight, and standard functional outcomes with a view to offering insight into the recovery process. The present finding that hip fracture patients showed unequal levels of strength between those of the affected side and unaffected side, as well as weakness of both the hip flexors and knee extensors or both, regardless of duration since injury, and regardless of whether they were receiving therapy or not, may help to explain the functional declines, as well as the proclivity for falls and further injury this group often exhibits. While problems in the case of knee extensor muscles have been identified by several authors post hip fracture injury, for example in recent findings of Sherrington et al. [22] and Madsen et al. [25], no

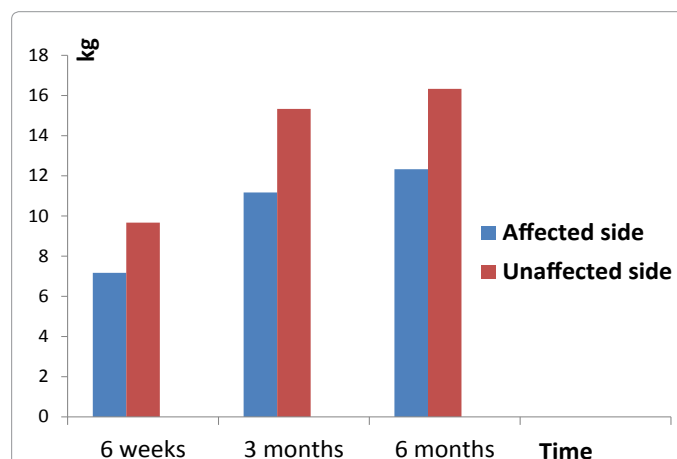
prior work to our knowledge has identified similar trends for the hip flexor muscles, which are key to functions such as walking, sitting to standing functions, and stair climbing.

In a more extensive series of observations [26] we found the observed strength deficit after hip fracture surgery did not seem related to the side of the body injured, gender or age, and in this case series we found similar trends when only females were studied, and the side injured was their dominant side. Our observations for the knee extensors which are very close to those of previous investigators in



Note: The strength differential between that recorded at 6 weeks and that recorded at 6 months using a paired t-test was significant only for the uninjured side, $p=.006$

Figure 1: Hip flexor strength differentials among the six hip fracture patients in (kg) over time.



Note: The strength differential between that recorded at 6 weeks and that recorded at 6 months using a paired t-test was $p=.054$ for the injured side; and non-significant for the uninjured side, $p=.150$

Figure 2: Knee extensor strength differentials among the six hip fracture patients in (kg) over time.

	6 weeks	3 months	6 months
Hip flexor muscles	42.6	41.6	42
Knee extensor muscles	39	46	46

Table 2: Asymmetry scores with respect to the hip flexor and knee extensor strength ratios recorded over time for 6 hip fracture surgical cases showing less than optimal recovery at 6 months, and where a score of 50=symmetry from side to side.

	6 weeks	3 months	6 months
<i>Hip</i>			
Affected vs unaffected leg	.13	.77	.86
<i>Knee</i>			
Affected vs unaffected leg	.80	.72	.56

Table 3: Pearson (r) correlations of strength scores for selected variables.

	6 weeks	3 months	6 months
<i>Affected Side</i>			
Hip strength vs knee strength	.25	.64	.35
<i>Unaffected side</i>			
Hip strength vs knee strength	.42	.64	.74

Table 4: Pearson (r) correlations of strength scores for selected variables.

terms of outcome and strength magnitudes (e.g. 27) suggest our data are reliable despite a limited sample size. In addition to knee extensor muscle weakness, which has been implicated in a number of studies as an independent contributor to a hip fracture, the finding of hip flexor muscle weakness in all the present cohorts with acute fractures, even after they have returned home following standard rehabilitation, and which was present at baseline to a greater degree on the uninjured side in one subject, may imply a problem predating the injury, which is compounded by surgery. The fact that strength of the uninjured leg increased over time for both muscle groups, and this was significant for the hip flexors on the uninjured side, but not the injured side, may not only point to a preceding strength deficit which affects both limbs, but that this deficit is compounded by the injury and surgical procedures, regardless of whether the person undertakes exercise or not. Although strength gains for the knee extensors were more marked for the injured leg on average, which is consistent with findings of others [27,28] the intra-limb strength correlations shown in Table 4-strongly suggests that the affected side has not yet matched the unaffected side as a whole in terms of extent of strength gains at six months.

As well as the resection of muscles at the hip which extend the knee, muscle weakness in the first year after surgery [28] could explain the slow rate of mobility recovery. At the same time, pain that persists after hip fracture, along with skeletal muscle weakness of the fractured leg may contribute to further pain and less desire to be active [29,30] even though the present subjects were not complaining overtly of pain at six months. The presence of prolonged strength deficits among fallers who have fractured their hip could increase the risk for further falling in the post fracture period [31]. The presence of prolonged weakness and muscle imbalances may also increase the chances of adverse effects on bone health, muscle mass [32,33] as well as optimal mobility recovery [34].

Moreover, protective reflexes against perturbations which depend in part on appropriate timing of muscle contraction as well as the physiological quality of force generating mechanism of the lower limb may be impaired. Based on the present outcomes, it can also be conjectured a persistent degree of leg strength asymmetry between the hip flexor strength measures from side to side over time, will hamper walking endurance and the ability to rise from a chair unassisted. While this asymmetry tended to improve over time, it did not fully disappear as was observed by Portegijs et al. [30].

Thus, consistent with current literature that emphasizes the importance of leg strength in preventing falls and in maintaining functional ability, and that the complete recovery of lower extremity function may take many months of recuperation time [34], and that the recovery process may be quite variable [35], the present body of findings may indicate that treatments to specifically enhance strength

recovery of the hip flexors, along with the extensor muscles of hip fracture cohorts, which are systematically applied, as indicated, for an extended duration after surgery are advocated. As well, educational interventions and counseling that sensitizes patients and caregivers to the possibility of patient's incurring further dysfunction if exercise compliance is poor, may be extremely important in promoting long-term functional ability of these cohorts and in reducing some unwarranted functional complications after hip fracture surgery that can prove so devastating.

A further related implication of the present observations is that: as a potentially potent predictor of hip fracture surgery functional outcomes, contrary to current practices, hip flexor strength needs to be carefully and consistently evaluated bilaterally and treated accordingly post hip fracture surgery in order to promote functional independence and optimize the extent of mobility recovery of elderly hip fracture cohorts. Although all were presently taking vitamin D supplementation, it is possible the outcomes of strength recovery would be even more detrimental for those who are not taking supplements, as well as for those who have additional health challenges.

To avert suboptimal outcomes for all hip fracture surgical cases, routine baseline and follow up evaluations of hip flexor muscle strength along with knee extensor strength, followed by therapy tailored based on these results are hence strongly recommended so that therapy can be adjusted accordingly. Patients should continue to exercise until there is adequate or optimal concordance between the strength values generated for both muscles of both legs, as well as intra limb muscle balances are optimally restored. Specific exercises to improve balance capacity may be desirable, if non weight bearing exercise protocols do not influence balance capacity

In conclusion, despite the obvious limitations to the present observations, including sample selection, sample size, the method used to assess muscle strength, and the small numbers of outcome measures documented, it appears muscle strength of the affected and unaffected sides of cases who have fallen and sustained hip fractures are non-uniform between patients, and across sides and muscles, in the present case the hip flexors and knee extensors. Given that the results comport favorably with current investigative results of others, it is concluded they may be useful for directing future interventions and especially for highlighting the need to implement more careful initial evaluations, followed by tailored rehabilitation programs, and progressive evaluations, in light of the high variability presently observed in outcomes, which can clearly impact upon the individual functional outcomes. Since suboptimal muscle strength may be an important predictor of falls that lead to hip fractures, as well as adverse outcomes post fracture, a consistent emphasis on acknowledging the important role of muscle in both hip fracture prevention, and secondary prevention, is likely to yield substantive societal and individual returns on this investment.

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