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Anu Salpakoski

Mobility Recovery after Hip Fracture and Effects of a Multi-component Home-based Rehabilitation Program

JYVÄSKYLÄN YLIOPISTO

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ABSTRACT

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Most hip fracture patients have difficulties in regaining their pre-fracture level of mobility. Adequate mobility is required for participation in society and for preventing disability. The purpose of this thesis was to investigate walking recovery and underlying determinants early after discharge home from hospital and to investigate whether musculoskeletal lower body pain and the type of surgical treatment received was associated with mobility limitation and physical inactivity two to three years after a hip fracture. In addition, the effects of an individually tailored multi-component home-based rehabilitation program on mobility disability were studied.

This thesis is based on the data of two RCTs: Hip-Asymmetry and ProMo. Both studies investigated community-dwelling men and women over age 60 who had sustained a hip fracture. The baseline data of the Hip-Asymmetry study and full data of the ProMo study were used. The Hip-Asymmetry included 78 participants 0.7-7.5 years post hip fracture, and the ProMo 81 participants with a recent hip fracture. The ProMo was a yearlong multi-component home-based rehabilitation intervention aimed to restore mobility after a hip fracture. The primary outcomes were self-reported mobility difficulties in moving, negotiating stairs, walking outdoors and walking 500 meters. Physical activity was assessed YPAS and musculoskeletal pain with the VAS.

Participants experienced major difficulties in walking outdoors on average 10 weeks post fracture. The use of walking aids and falls before the fracture, a longer inpatient period and musculoskeletal pain predicted catastrophic decline in walking ability after the hip fracture. In addition, the internal fixation induced more pain (p=0.005-0.008) and perceived mobility difficulties (p=0.010-0.018) than hemi-arthroplasty or total hip replacement on average 1.9 years post hip fracture, and severe pain was a risk factor for physical inactivity (OR 3.5, CI 95% 1.30–9.39) on average 3.3 years post hip fracture. The ProMo rehabilitation improved perceived difficulties in negotiating stairs over standard care (p=0.001). After the rehabilitation the mobility of the intervention group was even better than before the fracture. Novel approach of the study showed that, mobility recovery followed the logic of the re-ablement pathway among the intervention group, but not among the controls receiving standard care. In the intervention group, fewer difficulties in negotiating stairs at 6 and 12 months correlated with better balance 3 months before (p=0.007 and p<0.001, respectively).

The underlying determinants for mobility limitation should be acknowledged in clinical practice when designing outpatient rehabilitation after a hip fracture. With a yearlong multi-component home-based rehabilitation, mobility can recover to the pre-fracture level or even beyond. Outpatient rehabilitation should be persistent and progressive and guidelines for current practice should be improved.

Keywords: hip fracture, rehabilitation, mobility, physical activity, pain, aging

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Laukaa, August 2014

Anu

LIST OF ORIGINAL PUBLICATIONS

The thesis is based on the following original publications, which will be referred to in the text by their Roman numerals.

I Salpakoski A, Kallinen M, Kiviranta I, Alen M, Portegijs E, Rantanen T, Sipilä S. Type of surgery is associated with pain and physical function among older people with previous hip fracture: a cross-sectional case control study. *Submitted*

II Salpakoski A, Portegijs E, Kallinen M, Sihvonen S, Kiviranta I, Alen M, Rantanen T, Sipilä S. 2011. Physical inactivity and pain in older men and women with hip fracture history. Gerontology 2011; 57 (1), 19-27. doi: 10.1159/000315490. Epub 2010 May 28.

III Sipilä S*, Salpakoski A*, Edgren J*, Heinonen A, Kauppinen M, Arkela-Kautiainen M, Pesola M, Sihvonen S, Rantanen T, Kallinen M. 2011. Promoting mobility after hip fracture (ProMo): study protocol and selected baseline results of a year-long randomized controlled trial among community-dwelling older people. BMC Musculoskeletal Disorders 7 (12), 277. *Equal contributors

IV Salpakoski A, Törmäkangas T, Edgren J, Sihvonen S, Pekkonen M, Heinonen A, Pesola M, Kallinen M, Rantanen T, Sipilä S. 2014. Walking recovery after a hip fracture: a prospective follow-up study among community-dwelling over 60-year old men and women. Biomed Research International 2014:289549. doi: 10.1155/2014/289549. Epub 2014 Jan 6.

V Salpakoski A, Törmäkangas T, Edgren J, Kallinen M, Sihvonen S, Pesola M, Vanhatalo J, Arkela M, Rantanen T, Sipilä S. 2014. Effects of multi-component home-based physical rehabilitation program on mobility recovery after hip fracture: a randomized controlled trial. Journal of Ameriacn Medical Directors Association 15 (5), 361-8. doi: 10.1016/j.jamda.2013.12.083. Epub 2014 Feb 20.

ABBREVIATIONS

ABC	Activities-Specific Balance Confidence scale
ADL	Activities of Daily Living
AM-PAC	Activity Measure for Post-Acute Care
ANOVA	Analysis of Variace
BBS	Berg Balance Scale
BDI-II	Beck Depression Inventory
CES-D	Center for Epidemiologic Studies Depression Scale
CI	confidence interval
CBI	Coping Behaviors Instrument
DXA	Dual-energy X-ray absorptiometry
EPESE	Established Populations for Epidemiologic Studies of the Elderly
FAI	Frenchay Activities Index
FES	Falls Efficacy Scale
FIM	Functional Independence Measure
GDS	Geriatric Depression Scale
GEE	Generalized Estimating Equation
HA	hemiarthroplasty
Hb	Hemoglobin
hCRP	C-reactive protein
IADL	Instrumantal Activities of Daily Living
IAM	Instrumental Activity Measure
ICD	International Statistical Classification of Diseases and Related Health Problems
IF	internal fixation
LEP	leg extension power
MLE	maximum-likelihood estimation
mmHg	millimeters of mercury
MMSE	Mini-Mental State Examination
N	Newton
NS	non-significant
OR	odds ratio
PADL	Performance Activities of Daily Living
POMA	Performance-Oriented Mobility Assessment
RCT	randomized controlled trial
REF	reference group
ROM	range of motion
SD	standard deviation
SF-36	36-Item Short Form Survey
SPPB	Short Physical Performance Battery
THR	total hip replacement
TUG	Timed Up-and-Go

VAS	Visual Analog Scale
W	Watt
WHOQOL-BREF	The World Health Organization Quality of Life, brief
YPAS	Yale Physical Activity Survey

FIGURES

TABLES

CONTENTS

1 INTRODUCTION

Hip fracture is one of the most serious traumas among older people, as it can lead to various physical limitations and disabilities. The average age of a hip fracture patient is approximately 80 years (Korhonen et al. 2013), which means that patients often have other disabilities and diseases as well. Therefore hip fracture is not only an orthopaedic concern but also a geriatric concern (Taylor, Barelli & Harding 2010). This renders treatment and rehabilitation even more challenging in the short and long term.

Poor recovery after hip fracture causes considerable suffering for the patient and high costs for the health care sector. In Finland, the mean cost of treating a hip fracture during the first year post fracture is almost 20 000 € (Sund et al. 2011). Ten percent of hip fracture operations require reoperations, which further increases direct health care costs (Luthje et al. 2013). The number of hip fractures is increasing with population ageing. However, global variation has been reported in incidence rates and future forecasts (Kanis et al. 2012). In Finland, approximately 7 600 hip fractures occur annually (Korhonen et al. 2013). Although incidence rates have declined in recent years, the total number of hip fractures is expected to rise along with the increase in the number of people surviving to advanced age (Kannus et al. 2006, Korhonen et al. 2013). Risk factors for hip fractures include, for example, older age, female gender, use of walking aids, muscle weakness, impaired balance, polypharmacy and comorbidities (Feskanich, Willett & Colditz 2002, Kauppi et al. 2014, Luukinen et al. 1997, Marks et al. 2003, Norton et al. 1999, Norton et al. 2001, Pekkarinen, Loyttyniemi & Valimaki 2013, Shumway-Cook et al. 2005, Stolee et al. 2009).

Mobility recovery after hip fracture is challenging, and most patients do not regain their pre-fracture physical capacity or mobility ability (Visser et al. 2000, Vochteloo et al. 2013, Young, Fried & Kuo 2010). Adequate mobility is required not only for participation in society but also to prevent more serious complications such as a second hip fracture or institutionalization and early mortality (Abrahamsen et al. 2009, Gill et al. 2013a, Leibson et al. 2002). High age, pre-fracture mobility limitations, type of fracture, delayed surgery and surgical treatment are associated with mobility limitations and disability after hip fracture (Aktselis et al. 2014, Gjertsen et al. 2010, Kristensen et al. 2010, Stoen et al. 2014, Vochteloo et al. 2013, Yli-Kyyny et al. 2014, Yonezawa et al. 2009).

Having sufficient muscle strength is a prerequisite for mobility. Hip fracture decreases lower extremity muscle strength, especially in the fractured leg, which leads to asymmetrical muscle strength and power deficit (Kneiss et al. 2012, Portegijs et al. 2009, Young, Fried & Kuo 2010). Impaired muscle strength is further associated with musculoskeletal pain, poor balance, walking limitations and poor mobility (Herrick et al. 2004, Portegijs et al. 2005, Visser et al. 2000). Impaired balance and poor balance confidence (Sherrington & Lord 1998, Sihvonen et al. 2009) are associated with further mobility limitations (Jellesmark et al. 2012, Portegijs et al. 2012) and with physical disability (Edgren et al. 2013). In particularly, the ability to perform tasks requiring the production of high muscle forces combined with maintaining an upright posture and balance, such as when negotiating stairs, recovers slowly after hip fracture (Shyu et al. 2004). In addition, musculoskeletal pain is common, even years after the hip fracture (Herrick et al. 2004, Dasch et al. 2008). Musculoskeletal pain impairs balance and mobility, for example by restricting painful movements. Those restrictions might induce further pain causing overall activity restrictions, reduction in muscle strength and accelerated mobility limitation and disability.

Although the recovery of hip frcture patients has been widely studied, no generally accepted rehabilitation guidelines exist in the outpatient setting for mobility recovery after a hip fracture (Handoll et al. 2009, Handoll, Sherrington & Mak 2011, Ftouh et al. 2011). Rehabilitation after a hip fracture should aim to improve overall physical performance, restore patients´ mobility to the pre-fracture state and prevent further development of disability (Eilat-Tsanani et al. 2012, Handoll, Sherrington & Mak 2011).

Organizing outpatient rehabilitation could be more feasible in the home setting than center-oriented rehabilitation, which might be inaccessible for patients with poor health and major mobility limitations. While home-based rehabilitation is more achievable, however, the actual intensity of rehabilitation and compliance are difficult to ensure. Rehabilitation can also be divided into specific and multi-component rehabilitation. Specific rehabilitaion means training one component or one physical characteristic only. Multi-component rehabilitation aims to improve multiple physical functions simultaneously. Multi-component home-based rehabilitations are cost-effective, easy to assess and achievable for patients who have recently been discharged home from hospital and might have overwhelming barriers to leaving their homes because of poor mobility.

The lack of long-term multi-component home-based rehabilitation is acknowledged. Ten previous studies on seven different trials have been conducted (Crotty et al. 2002, Crotty et al. 2003, Latham et al. 2014, Orwig et al. 2011, Shyu et al. 2010, Tinetti et al. 1999, Tsauo et al. 2005, Tseng, Shyu & Liang 2012, Ziden, Frandin & Kreuter 2008, Ziden, Kreuter & Frandin 2010), but evidence of the effects on mobility limitation and disability remains conflicting.

The aim of this thesis was to investigate walking recovery and underlying determinants early after discharge home from hospital and to investigate whether musculoskeletal lower body pain and the type of surgical treatment received was associated with mobility limitation and physical inactivity two to three years after a hip fracture. In addition, the effects of an individually tailored multi-component home-based rehabilitation program on mobility disability were studied. This thesis focused on community-dwelling men and women over age 60 who had sustained a hip fracture.

2 REVIEW OF THE LITERATURE

2.1 Epidemiology of hip fractures

The mean age of hip fracture patients has increased on the last few decades. However, mortality rates have stabilized, which might be associated with better medical and surgical management in recent years (Haleem et al. 2008). In addition, the occurrence of intracapsular hip fractures seems to have decreased compared to extracapsular fractures, which are more related to older age (Haleem et al. 2008).

2.1.1 Definition and incidence of hip fractures

Fracture of the proximal femur, commonly referred to as hip fracture, is a serious accident among older people (Marks et al. 2003, Kristensen 2011). Hip fractures are usually caused by low-energy trauma, such as a fall, a slip or a stumble. Hip fracture patients are very heterogeneous group in terms of pre-fracture health and functional status (Penrod et al. 2007). The majority are over 50 years old and incidence rates increase with increasing age (Parker & Johansen 2006, Ensrud 2013). Three-quarters of all hip fracture patients are women (Burge et al. 2007). The reasons for the higher rates among women are, for example, menopause and its consequences on bone strength (Baccaro et al. 2013, Ensrud 2013), and longer life expectancy (Cummings & Melton 2002).

The number of hip fractures has increased rapidly during the last few decades. There are clear global differences in incidence rates and future predictions (Kanis et al. 2012). It is noteworthy that, based on hip fracture rates, many Western countries e.g. most of the European counties and North America are nowadays categorised as high or moderate risk countries for hip fractures, while e.g. Latin America, Africa and many Asian countries are low risk regions for hip fractures (Kanis et al. 2012). The reasons for different hip fracture rates between countries are not clear. However, a decline in incidence rates recently has been observed e.g. in Finland (Korhonen et al. 2013), Sweden (Nilson et al.

2013), Denmark (Abrahamsen & Vestergaard 2010), Australia (Cassell & Clapperton 2013), the USA (Stevens & Rudd 2013) and Greece (Lyritis et al. 2013). In Germany (Icks et al. 2013) and Morocco (El Maghraoui et al. 2013), the incidence rates have recently stabilized. However, in Serbia (Senohradski et al. 2013), Iran (Maharlouei et al. 2014) and Japan (Hagino et al. 2009) the incidence continues to increase.

Approximately 7600 hip fractures occurred in 2010 among Finns aged over 50 years (Korhonen et al. 2013). The average age of Finnish hip fracture patients is 81.6 years for women and 76.0 years for men (Korhonen et al. 2013). In Finland, the incidence of hip fractures increased up to the end of the 1990s (Kannus et al. 1999) and declined thereafter (Kannus et al. 2006, Korhonen et al. 2013), especially among women and persons over age 65 (Korhonen et al. 2013). The reasons for the decline are unclear, but better overall health and physical function, fall prevention programs, increased body weight and better osteoporosis prevention, interventions for polypharmacy, modifications of environmental hazards and increased D-vitamin intake among older people might partly explain the decline. Although the incidence has declined, the total number of hip fractures is expected to rise due to population ageing. If the incidence stabilizes to the level of 2010 and population ageing occurs as predicted, the total number of hip fractures is predicted to almost double (13 500) by the year 2030 (Korhonen et al. 2013).

2.1.2 Risk factors for hip fracture

Key factors associated with risk for hip fractures are the same as the major causes of falls, such as high age, female gender, institutionalization, low weight, use of assistive devices, low physical activity, muscle weakness, impaired balance, impaired vision, polypharmacy, cognitive impairment, smoking and comorbidities (Feskanich, Willett & Colditz 2002, Kauppi et al. 2014, Luukinen et al. 1997, Marks et al. 2003, Norton et al. 1999, Norton et al. 2001, Pekkarinen, Löyttyniemi & Välimäki 2013, Shumway-Cook et al. 2005, Stolee et al. 2009). Risk for falls and fractures, is higher among people with multiple risk factors (Cummings et al. 1995). Most hip fractures occur after a fall, but in only one per cent of all falls among older women is the outcome a hip fracture (Cummings & Melton 2002). This indicates that whether or not a hip fracture is sustained depends on bone structure and the biomechanics of falling (Cummings & Melton 2002, Mikkola et al. 2007). Osteoporosis and low bone mass are among the major risks for hip fractures after a fall (Cummings & Melton 2002, Mikkola et al. 2007) especially for femoral neck fractures (Fox et al. 2000). Due to hormonal changes during ageing and the menopause, women tend to have greater bone loss than men and consequently higher fracture risk (Baccaro et al. 2013, Ensrud 2013). Low body mass and weight loss in adult life is associated with increased hip fracture risk (Farahmand et al. 2000). In addition, a previous fracture is a strong risk factor for subsequent hip fractures (Ensrud 2013). Lower exposure to sunlight and UV radiation and northern latitude has also been associated with increased hip fracture rates (Nilson, Moniruzzaman & Andersson 2013).

While the risk factors for hip fractures are widely known, their prevention is difficult owing to lack of precise knowledge of the factors underlying the mechanism of accidental fractures (Marks et al. 2003). Often no single factor has been identified as responsible for a hip fracture and thus the pathology of hip fractures is multifactorial (Ensrud 2013, Parker & Johansen 2006). Consequently, effective overall rehabilitation of the hip fracture patients is essential to prevent repeated fractures in the future.

2.1.3 Fracture types and surgical treatment of hip fractures

Fracture types. Hip fractures fall into two basic categories: intracapsular and extracapsular fractures (Figure 1). More specifically, hip fractures are subdivided by their location, viz. femoral head (ICD 10 International Classification of Diseases, S72.0), femoral neck (S72.0), and pertrochanteric (S72.1), intertrochanteric (S72.1) and subtrochanteric (S72.2) area. Femoral head and neck fractures are commonly called femoral neck fractures and pertrochanteric and intertrochanteric fractures are referred to as trochanteric fractures.

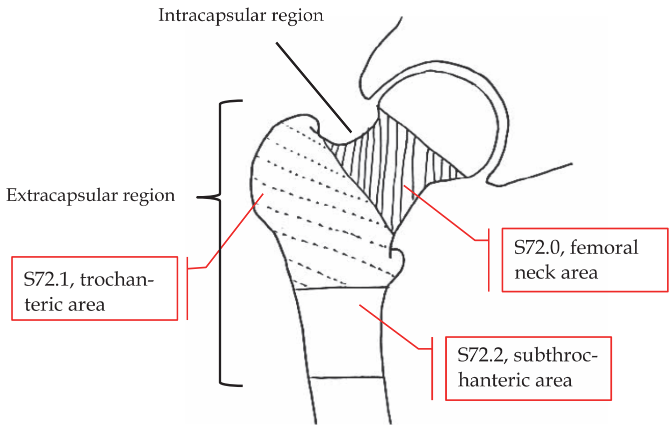

FIGURE 1 Classification of hip fracture type by its location.

Femoral neck fractures can further be divided into subcapital, transcervical and basicervical fractures, again according to their precise location. In addition, femoral neck fractures are classified by the displacement of the fractured bone (Marks et al. 2003, Bernstein & Ahn 2010). The most commonly used displacement and fracture level classification is the four-level categorization of Garden, which proceeds from I (incomplete fracture) to IV (complete fracture and fully displace) (Garden 1961). Trochanteric fractures can be roughly divided into stable and unstable fractures according to the fragmentary nature of the fracture area, but for extracapsular fractures no universally accepted classifications exist (Ahn & Bernstein 2010).

This thesis investigates femoral neck and trochanteric fractures, which account for almost all hip fractures among older people. For example, in the

Central Finland Health Care District during the years 2002-2003, 60.8% of all treats were femoral neck fractures, 31.5% trochanteric fractures and only 7.6% subtrochanteric fractures (Lönnroos et al. 2006).

Surgical treatment. Hip fractures can be treated surgically or conservatively. Conservative treatment is mainly used among institutionalized, immobile patients (Jain, Basinski & Kreder 2003).

Hip fracture surgery should be performed as soon as health of the patient enables it (Hung et al. 2012). A short time from fracture to surgery has been associated with less pain, a shorter inpatient period, earlier mobilization and fewer surgical complications (Orosz et al. 2004, Chong, Savige & Lim 2010). Hip fractures can be treated surgically in various ways: total hip replacement, hemiarthroplasty (unipolar vs. bipolar, cemented vs. uncemented), screws, pins, sliding hip screw, intramedullary nail or fixed angle plate (Bernstein & Ahn 2010, Ahn & Bernstein 2010). The surgical approach varies as well: injury can be approached from the posterior or anterior side of the hip, or in some cases both approaches are required (van der Grinten et al. 2011). The treatment decision depends on the fracture itself but also on the practice of the individual surgeon and the operating unit (Bernstein & Ahn 2010).

Surgical treatment for nondisplaced or minimally displaced femoral neck fractures is usually performed with screw, or plate and screw fixation (Hung et al. 2012, Bernstein & Ahn 2010). Hemiarthroplasty and total hip replacement are mostly used for displaced femoral neck fractures (Hung et al. 2012). Total hip replacement is recommended for younger and physically active patients, because hemiarthroplasty is more sensitive to dislocation and related reoperations (Keating et al. 2006). Total hip replacement is associated with better functional outcomes than hemiarthroplasty, but complications, including blood loss are greater with total hip replacement surgery (Blomfeldt et al. 2007). There is evidence that uncemented hemiarthroplasty leads to impaired mobility, induces more post-operative pain (Parker, Gurusamy & Azegami 2010, Li et al. 2013), mechanical complications of the device (Yli-Kyyny et al. 2014, Li et al. 2013) and increased reoperation rates (Gjertsen et al. 2012, Yli-Kyyny et al. 2014) compared to cemented hemiarthroplasty. In contrast, a recent five-year follow-up study, randomized by surgical method after femoral neck fracture, reported better hip function measured by the Harris Hip Score for uncemented than for cemented hemiarthroplasty (Langslet et al. 2013). Another randomized controlled trial for displaced femoral neck fractures reported better quality of life two years after bipolar hemiarthroplasty compared to unipolar hemiarthroplasty, but no differences were found in hip functioning, reoperation rates or mortality (Inngul et al. 2013). When comparing internal fixation and arthroplasty, fixation has been reported to induce more residual hip pain during the first post-fracture years (Gjertsen et al. 2010, Lu-Yao et al. 1994). Also shortening of limb length and limitations in limb range of motion are more common after fixation than after arthroplasty (Parker et al. 2002). Femoral neck shortening after internal fixation induces walking asymmetry, decreased walking velocity and impaired physical functioning, leading to permanent physical limitations (Zielinski et al. 2013). The results of a recent randomized controlled trial suggested that physical functioning, activities of daily living and quality of life favored hemiarthroplasty compared to internal fixation in the first two years, but statistically significant differences between the two surgical methods were no longer found six years after the hip fracture (Stoen et al. 2014). Nevertheless, reoperation rates were significantly higher after internal fixation than after hemiarthroplasty (Stoen et al. 2014). Currently there is no clear consensus or best practice regarding the type of surgical method for femoral neck fractures, in part because of the variety of different implants used in clinical trials (Parker, Gurusamy & Azegami 2010) and in part owing to difficulty in explaining the results due to the high mortality rates in longer follow-ups (Gjertsen et al. 2008, Bernstein & Ahn 2010).

Depending on the level of stability of the fracture, patients with trochanteric fractures are often fixed with a sliding hip screw or intramedullary nail (Hung et al. 2012). Stable trochanteric fractures are often fixed with sliding hip screw, but a lateral plate with fixed-angle screws can be used as well, especially to prevent shortening (Ahn & Bernstein 2010). An intramedullary nail is often used for unstable trochanteric fractures (Ahn & Bernstein 2010). In rare cases a trochanteric fracture can be treated with hemiarthroplasty. The differences in the rates between intramedullary nail and sliding hip screw recovery reported by randomized controlled trials are both minimal and conflicting (Aktselis et al. 2014, Huang et al. 2013, Matre et al. 2013, Parker, Bowers & Pryor 2012). Better mobility (Parker, Bowers & Pryor 2012) and quality of life (Aktselis et al. 2014), however, have been indicated after intramedullary nail surgery. Regions and surgeons differ in which fixation methods are used for trochanteric fractures, and hence there are no clear results as to which method is best for a trochanteric fracture (Bhandari et al. 2009, Huang et al. 2013, Marks et al. 2003).

The healing of femoral neck fractures might be impaired if the retinacula vessels in the femoral capsule are damaged, especially in displaced fractures (Parker & Johansen 2006). Risks after a femoral neck fixation are osteonecrosis and nonunion, especially with displaced fractures and if time from fracture to surgery is prolonged (Bernstein & Ahn 2010). Possible complications after arthroplasty are dislocation, infection and loosening (Bernstein & Ahn 2010). Trochanteric fractures heal more easily, because the fracture is near to the metaphysis, which makes union of the fracture more likely (Ahn & Bernstein 2010). However, the trochanteric fracture itself can cause substantial blood loss and need for fluid and blood transfusion (Parker & Johansen 2006).

All the above-mentioned surgical methods are still widely used in hip fracture operations. Age, co-morbidity and other diseases, together with fracture type determine the type of fixation that is chosen (Tidermark et al. 2003). Type of surgical treatment is associated with mobility recovery and pain, as described earlier. To optimize rehabilitation and pain management strategy after hip fracture, we need to understand the factors underlying poor vs. successful recovery.

2.2 Challenges in mobility recovery after hip fracture

The physical consequences as well as the recovery process after a hip fracture are multidimensional. The physical limitations are often related and occur simultaneously, presenting a challenge for the recovery and rehabilitation (Kristensen 2011). Impaired mobility after a hip fracture hinders coping independently in the community.

2.2.1 Mobility limitations and disability

Definition of mobility. Relating to healthy aging, optimal mobility means that the individual is safely and reliably able to go where s/he wants, when s/he wants to go and how s/he wants to get there (Satariano et al. 2012). In general, mobility refers to the ability to move, without or with assistance indoors and outdoors. It includes, for example, moving from one place to another, like from a bed to a chair, walking, performing daily tasks, exercising, driving a car, and using public transportation (Satariano et al. 2012). In this thesis, mobility refers to basic movements such as rising from a chair, moving from one place to another such as from a bed to a chair, negotiating stairs and walking. All those tasks require carrying one´s own weight.

Measuring mobility limitation and disability. Mobility limitation can be measured with self-reported or performance-based measurements, or both, as they complement each other by providing an understanding of mobility in different situations and conditions. Both assessments are equally sensitive for changes (Latham et al. 2008). The self-reported versus performance-based types of mobility assessments in part measure different outcomes, while psychological and emotional factors related to self-efficacy have a more marked effect on self-reported mobility (Farag et al. 2012). Performance-based assessments are usually performed in optimal laboratory or home settings free of mobility barriers. Performance-based measurements often assess the upper limit of physical capacity (Latham et al. 2008). For example, when measuring maximal walking speed over a short distance, participants might be able to walk fast despite feeling pain or fatigue and would not be able to maintain the same pace over longer distances, such as are typically present in the community. Self-reported measurements relate more closely to the situations people face in every day life. While performance-based and self-reported mobility measurements appear to assess slightly different constructs, they provide complementary information about mobility recovery after a hip fracture (Farag et al. 2012).

Mobility limitation and disability after hip fracture. Changes in the prerequisites of mobility resulting from ageing or diseases (like a hip fracture), can lead to mobility restrictions, limitations and further mobility disability (Guralnik et al. 1995). In particular, restricting the participation of community-dwelling people in activities outside the home due to the inability to move independently can further lead to becoming a homebound (Wilkie et al. 2006).

Most hip fracture patients have difficulties in regaining their pre-fracture level of physical capacity and mobility ability (Alley et al. 2011, Bernstein & Ahn 2010, Rogmark & Johnell 2005, Visser et al. 2000, Vochteloo et al. 2013, Young, Fried & Kuo 2010), especially with advancing age (Penrod et al. 2008). For example, according to Visser et al. (2000) as long as a year after a hip fracture only less than one fifth (18%) of their participants had recovered to their pre-fracture level in bed rise, walking ten feet, chair rise, walking one block and negotiating stairs. In addition, most patients need walking aids for several months after the fracture or even permanently (Endres et al. 2006, Ganz et al. 2007). Taylor et al. (2010) reported reduced walking ability, outdoor mobility, and participation in community activities three months after discharge compared to the pre-fracture level. Physical activity after a hip fracture has shown to speed up functional recovery (Talkowski et al. 2009), but up to two years after a hip fracture, a significant decrease in mobility and physical activity was found in fracture patients when compared to the controls without a previous hip fracture (Norton et al. 2000). In one study, participants were able to complete walking tasks similar to that of walking in the community immediately after discharge (Dennett, Taylor & Mulrain 2012). However, although those participants managed to do single tasks, they perceived significant mobility restrictions and lack of confidence in their everyday life (Dennett, Taylor & Mulrain 2012).

Natural healing and the regaining of mobility during the first few months after a hip fracture is fast, but thereafter the rate of improvement in mobility falls (Alley et al. 2011, Shyu et al. 2004, Vochteloo et al. 2013). Mobility functions do not all recover simultaneously. More demanding tasks, like negotiating stairs, in particular, need a longer time to regain the pre-fracture level (Magaziner et al. 2000, Shyu et al. 2004). Moreover, these mobility tasks are important for coping in everyday life (Shyu et al. 2004, Visser et al. 2000, Laukkanen et al. 1994, Laukkanen et al. 1997). In addition, it is known that the ability to negotiate stairs usually recovers approximately a year after a hip fracture, and sometimes not even then (Ariza-Vega, Jimenez-Moleon & Kristensen 2013, Magaziner et al. 2000, Shyu et al. 2004).

Disablement and re-ablement. The disablement process, which describes the pathway from disease to disability, was used as the framework for this research (Figure 2) (Verbrugge & Jette 1994). According to this pathway, the specific pathology - referring to diseases or injuries (in this thesis hip fracture) - influences specific body systems, possibly causing impairments (e.g. muscle strength). These impairments in turn lead to functional limitations (e.g. decreased balance) and possibly later on disability, which describes the difficulty experienced in performing the tasks needed for daily living in the community (e.g. difficulty in negotiating stairs). This thesis studies rehabilitation as a way of modifying the disablement process. The model of the disablement process is used as the basis for hypothesizing that the mobility recovery process includes processes similar to those in the disablement process, but in this case the reverse, i.e. leading toward improvement in functioning. This pathway could be characterized as re-ablement in contrast to disablement.

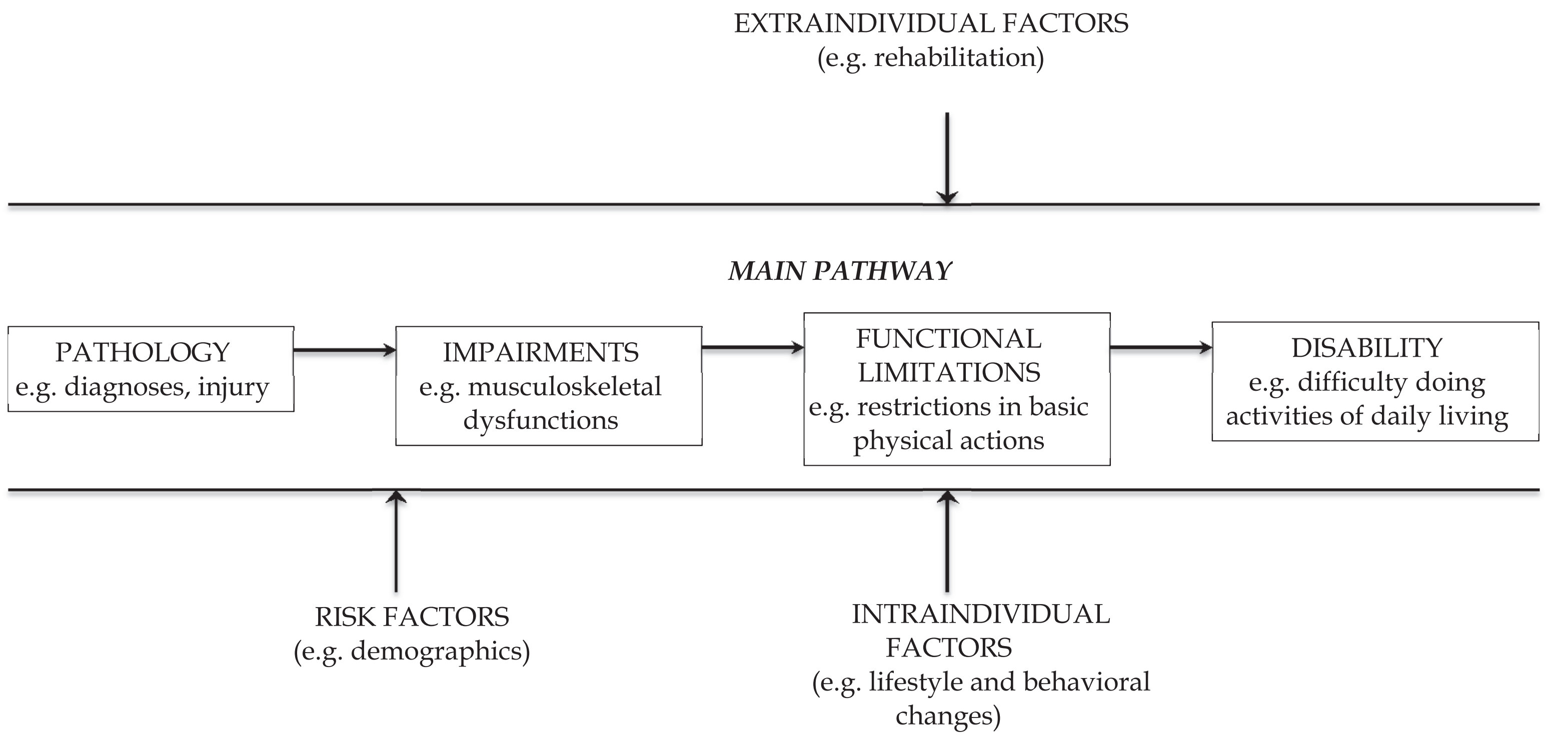

FIGURE 2 The pathway of disablement process (Verbrugge & Jette 1994) added with the hypothetical model of re-enablement.

Previous experimental studies after a hip fracture have mainly focused on single outcome measures, rather than viewing recovery as a holistic process in which physical characteristics are associated with each other. For an optimal rehabilitation outcome, it would be logical to acknowledge the complexity of mobility recovery and to target and follow up the various functional tiers along the path to disablement. To our knowledge, previous studies investigating mobility recovery after a hip fracture have not been conducted in the context of disablement process.

2.2.1.1 Decreased muscle strength and muscle power

Voluntary joint movements (e.g. knee extension) and the maintenance of body posture (e.g. standing position) require synchronized functioning of the neuromuscular system. Skeletal muscle contraction produces force (Enoka 1994). Muscle contraction can be isometric or dynamic. During isometric contraction, muscle length and joint angle do not change as the load is equivalent to the force produced or the muscles are working against an immovable resistance. During dynamic muscle contractions, muscle length and joint angle change. When force production is greater than the external load, the muscle shortens (concentric contraction), whereas when the external load is greater than muscle force produced, the muscle lengthens (eccentric contraction) (McArdle, Katch & Katch 2000). Muscle power is a product of force and velocity, and it refers to the ability of the neuromuscular system to produce force quickly (Enoka 1994). Measurements of muscle force and muscle power are used as indicates of muscle strength. Muscle force, in particular, is often viewed as an indicator of muscle strength, which then refers to a fitness characteristic of an individual.

Muscle force and power decrease with age. Previous studies have suggested that muscle power might be more closely related to mobility among older disabled people than muscle strength (Bean et al. 2003, Bean et al. 2010, Cuoco et al. 2004). Among younger people muscle strength increases during the recovery phase, but among older people muscle strength or power might not recover to the pre-injury level without targeted rehabilitation. One of the main causes for long-term mobility restrictions after a hip fracture is a decrease in lower extremity muscle strength, which might derive from post-operative weight-bearing limitations. Seven months after hip fracture, muscle strength was still less than half that of age-matched controls (Sherrington & Lord 1998). Both the hip fracture itself and resultant surgery decrease lower extremity muscle strength (Young, Fried & Kuo 2010), especially in the fractured leg, resulting in asymmetrical muscle strength deficit (Portegijs et al. 2009, Kneiss et al. 2012). Lower extremity asymmetrical muscle strength or muscle power deficit refers to the difference between the dominant and non-dominant leg. Muscle strength deficit in hip fracture studies is usually defined as the reduction in the strength of the fractured leg compared to the strength of the non-fractured leg. A previous study showed that a mean asymmetrical deficit in leg extension power at one week after a hip fracture of 29% (50% represents equal legs), and at 13 weeks after fracture of 40% (Portegijs et al. 2008). It was also found that on average four years after a hip fracture, the lower leg extension power of the fractured leg continues to be significantly weaker (Portegijs et al. 2009).

Loss of muscle strength during the year after a hip fracture was associated with poor mobility (Visser et al. 2000). The ability to produce force quickly is relevant for mobility task that require force and velocity, such as negotiating stairs. Decreased muscle strength and muscle power deficit after a hip fracture have been associated with pain (Herrick et al. 2004), poor standing balance, slower walking speed, and increased risk for injurious falls (Portegijs et al. 2005, Portegijs et al. 2006).

2.2.1.2 Balance impairments

Sufficient postural balance is needed to maintain an upright posture when engaged in performing mobility tasks (Sakari et al. 2010, Tiedemann, Sherrington & Lord 2005). Balance can be divided into static (postural control) and dynamic (movement control) balance. The vestibular, visual, somatosensory and proprioceptive senses regulate balance performance. In addition, to the above-mentioned senses, muscle strength and environmental factors are associated with postural balance. Aging and illnesses impair the vestibular (Viljanen et al. 2009), visual (Kulmala et al. 2009) and somatosensory (Whipple et al. 1993) systems. Changes in the balance regulation mechanisms could lead to impaired balance and difficulties in performing mobility tasks.

Hip fracture leads to impaired postural balance and balance confidence (Sherrington & Lord 1998, Sihvonen et al. 2009, Taylor, Barelli & Harding 2010). The recovery of balance mostly occurs in the first six months after a hip fracture (Magaziner et al. 2000). Increased comorbidity, higher age, male gender and functional disability are associated with poorer balance recovery (Edgren et al. 2013, Radosavljevic et al. 2013). Recovery of the ability to perform tasks that require more strength and balance, such as the ability to negotiate stairs (Shyu et al. 2004, Magaziner et al. 2000) and sit–to-stand from a chair (Kneiss et al. 2012, Magaziner et al. 2000) is slow. Hip fracture patients have a tendency to use upper extremity assistance when rising from a chair because of asymmetrical strength in the lower extremities and impaired postural balance (Kneiss et al. 2012).

Fear of falling refers to a person´s perception of her/his ability to maintain balance, and includes a combination of other factors such as previous falls, pain and physical performance (Hadjistavropoulos, Delbaere & Fitzgerald 2011). It has been previously suggested that balance and walking ability mediate the association between fear of falls and fall risk (Hadjistavropoulos, Delbaere & Fitzgerald 2011). The majority of the participants with a previous fall experience fear of falling (Legters 2002), which is further associated with physical activity restriction (Delbaere et al. 2004, Legters 2002). In addition, fear of falling or in other words, decreased balance confidence is associated with mobility limitation (Jellesmark et al. 2012, Portegijs et al. 2012) and physical disability (Edgren et al. 2013). Patients with fear of falling had a 23-25% worse prediction for mobility recovery on the Timed Up-and-Go test eight weeks after a hip fracture surgery and for walking speed six months after surgery (Oude Voshaar et al. 2006). In addition, low balance confidence is associated with institutionalization and mortality after a hip fracture (Visschedijk et al. 2010).

2.2.2 Other serious consequences

Second hip fracture, institutionalization and mortality. Other serious complications after a hip fracture include a second hip fracture, institutionalization and mortality. During the first year after a hip fracture, approximately 5% of patients sustain a second hip fracture (Lloyd et al. 2009). The risk factors for a second hip fracture are similar to those for the first hip fracture, but the underlying causes for second hip fracture have been less investigated. The risks factors for a second hip fracture are higher age, female gender, decreased functional status, cognitive impairment and Parkinson´s disease (Berry et al. 2007, Rodaro et al. 2004, Yamanashi et al. 2005).

Hip fracture is a risk factor for institutionalization and death (Abrahamsen et al. 2009, Gill et al. 2013a, Leibson et al. 2002). Risk for institutionalization after a hip fracture diminishes over time, but remains elevated for years compared to controls matched for age and gender (Leibson et al. 2002). Cognitive impairments, delirium and depressive symptoms are associated with institutionalization and mortality after a hip fracture (Agusti et al. 2012, Edlund et al. 2001, Givens, Sanft & Marcantonio 2008, Lundström et al. 2003). In addition, living alone, higher age, physical disability and mobility limitation before the fracture were risk factors for institutionalization (Agusti et al. 2012, Vochteloo et al. 2012). Risk factors for mortality after a hip fracture are higher age, male gender, comorbidity, cancer, functional inability and treatment with opiates, delayed surgery, major postoperative complications and use of assistive devices (Agusti et al. 2012, Alegre-Lopez et al. 2005, Maggi et al. 2010, Paksima et al. 2008). Bone medication (Agusti et al. 2012, Nurmi-Luthje et al. 2011) as well as calcium and vitamin D supplements (Nurmi-Luthje et al. 2011) are associated with deceased mortality risk.

Health care costs. A hip fracture is a major burden not only for the patient but also for the health care sector. Although, not the most common type of fracture, the health care costs of treating hip fractures are high. For example, in the USA hip fractures account for 14% of all fractures but 72% of total fracture-related health care costs (Burge et al. 2007). Health care costs are high especially during the first post-fracture year. The costs rise two- to threefold with a second fall and fracture, or as a consequence of permanent institutionalization (Becker et al. 2010, Haentjens et al. 2001, Nurmi et al. 2003, Song et al. 2011).

The average cost of treating for a hip fracture in Finland during the first year after the fracture is almost 20 000 € (Sund et al. 2011). The direct health care costs of a reoperation were almost 13 000 €. In the case of infections, the mean costs were approximately 29 000 € (Luthje et al. 2013). According to a recent Finnish study, 10% of the hip fracture patients need to be re-operated (Luthje et al. 2013).

2.3 Rehabilitation after hip fracture

2.3.1 Rehabilitation in Finland

In Finland, primary and specialized health care are organized on the municipal level. All citizens have social insurance, which covers the most health care costs. The older persons participating in this study lived in the catchment area of the Central Finland Health Care District. The District comprises 21 municipalities with a total population of 275 161.

Primary health care, including inpatient care and an outpatient clinic is implemented at local municipal health care centers. Hip fracture surgery is performed within specialized health care at the Central Hospital of Central Finland, after which patients are transferred to a health care center in their municipality of residence for both inpatient care and rehabilitation. Transfer to a health care center occurs within the first few days after surgery, depending on the status of the patient. The normal inpatient period ranges from one week to few months, depending on care needs. In some cases, patients with a good recovery prognosis are directly discharged to home from the hospital.

2.3.2 Rehabilitation for mobility recovery after hip fracture

Need for rehabilitation. The fundamental aim of rehabilitation after a hip fracture is to improve overall physical performance (Handoll, Sherrington & Mak 2011) and to restore patients´ physical functioning to its pre-fracture level and prevent further development of disability (Eilat-Tsanani et al. 2012). Although, the recovery of hip frcture patients has been widely studied, no generally accepted rehabilitation guidelines for mobility and functional capacity recovery after a hip fracture exist (Handoll et al. 2009, Handoll, Sherrington & Mak 2011, Ftouh et al. 2011). One reason for the absence of guidelines might be the fact that hip fracture is at least as much a geriatric trauma than it is an orthopaedic one (Taylor, Barelli & Harding 2010). Hence rehabilitation needs attention from various health care professionals in different fields. It is stated that multidisiplinary team should design a tailored rehabilitation plan before discharge (De Rui et al. 2013). In addition, mobility disability is multidimensional, as mentioned earlier in the literature review, and the exact causalities between different factors are not known. Nevertheless, it is clear that a hip fracture could cause a vicious cycle leading to further decrease in mobility ability, if the patient is not sufficiently rehabilitated. Acknowledging individual needs for outpatient rehabilitation early enough during the period of hospitalization, makes it easier to plan effective rehabilitation. It is also important to ensure that the patient has a realistic understanding as it has been suggested that the inpatient period could rise too high self-confidence regarding patients´ functional abilities. It is essential that patients understand their potential mobility inability after discharge to home, when they are no longer receive full time support from nurses or other health and social care professionals (Taylor, Barelli & Harding 2010).

Arrangement of rehabilitation. Rehabilitation can be organized in a rehabilitation center, outpatient clinic or in the patient´s home. Center-oriented rehabilitation might be inaccessible for frail, recently discharged patients, for whom the barriers to leaving home might be overwhelming due to poor health and mobility limitation and disability. Home-based rehabilitation is more achievable, but the challenges are often lack of progressivity and intensity as well as compliance.

The rehabilitation of hip fracture patients after discharge can be divided into specific and multi-component rehabilitation. Specific rehabilitaion refers to training only one component (e.g. muscle strength or balance) or one physical characteristic (e.g. mobility). Multi-component rehabilitation aims to improve various physical functions by physical exercise (e.g. muscle strength and balance) as well as physical activity, functioning, self-confidence and other factors associated with more comprehensive rehabilitation outcomes. This thesis investigates a multi-component home-based rehabilitation program conducted among community-dwelling hip fracture patients over age 60 with a femoral neck or trochanteric fracture.

Multi-component home-based rehabilitation programs. The ProMo study investigated in this thesis was based on previously published research on home-based multi-component rehabilitation among community-dwelling frail older people (Gill et al. 2002). In their study, rehabilitation included instructions for safe moving and use of assistive devices, removing environmental hazards, and progressive exercise program. The rehabilitation reduced the progression of functional decline (Gill et al. 2002). These encouraging results suggested that a similar approach might also be efficacious among hip fracture patients.

Ten previously published multi-component home-based rehabilitation studies after a hip fracture, which investigated the effects of rehabilitation on mobility recovery compared to usual care, were found (Crotty et al. 2002, Crotty et al. 2003, Latham et al. 2014, Orwig et al. 2011, Shyu et al. 2010, Tseng, Shyu & Liang 2012, Tinetti et al. 1999, Tsauo et al. 2005, Ziden, Frandin & Kreuter 2008, Ziden, Kreuter & Frandin 2010). The studies include seven different trials, and from those, three trials included two separate papers. Of the ten studies, four were published before ProMo was launched. The studies are summarized in Table 1. Most of the trials started soon after the hip fracture, the earliest in the hospital immediately following a hip fracture (Shyu et al. 2010, Tseng, Shyu & Liang 2012) and latest approximately nine months after the fracture (Latham et al. 2014). The length of the interventions varied from one month to one year.

Two of the trials started before discharge from hospital, and included a geriatric consultation and supported discharge (Shyu et al. 2010, Ziden, Frandin & Kreuter 2008). The multi-component home rehabilitations included physical therapy, usually including strength, balance and stretching exercises, and in a few cases home environmental modifications.

Not only the content of the intervention, but also the mobility outcomes differed between the trials. The usual outcome variables of the trials were different composite scores, quality of life, and various modifications of the activities of daily living. Three studies found positive effects of the home-based rehabilitation for the measurements mentioned above (Latham et al. 2014, Orwig et al. 2011, Tinetti et al. 1999). Although outpatient rehabilitation usually consists of different mobility tasks and strength exercises, no clear advantages of a multi-component home-rehabilitation over usual care have been found in mobility recovery. Some of the trials included longer follow-up periods after the intervention, but when the effects of the intervention were compared to those of usual care during the intervention period, four studies found better mobility results after the intervention. Latham et al. (20014) reported better results in the Short Physical Performance Battery and functional balance, Orvig et al. (2011) higher physical activity, Shyu et al. (2010) increased quadriceps strength and walking ability, Tinetti et al. (1999) better upper extremity strength, and Crotty et al. (2002) less fear of falling for the intervention group than for the usual care group. Nevertheless a need for further studies of home-based rehabilitation programs among hip fracture patients is widely acknowledged (Handoll et al. 2009, Handoll, Sherrington & Mak 2011, Ftouh et al. 2011, Donohue et al. 2013).

Other studies on specific rehabilitation or multi-component rehabilitation in an outpatient clinic. Other previous studies have shown that strength training interventions lasting from one to four months and implemented in the home setting or in outpatient clinic, have had positive effects on lower extremity strength (Hauer et al. 2002, Mangione et al. 2005, Sherrington & Lord 1997, Sherrington, Lord & Herbert 2004, Sylliaas et al. 2011, Sylliaas et al. 2012a), balance (Sylliaas et al. 2011, Sherrington, Lord & Herbert 2004) and mobility (Hauer et al. 2002, Sherrington & Lord 1997, Sherrington, Lord & Herbert 2004, Sylliaas et al. 2011). In addition, a six-month multi-component rehabilitation at the outpatient clinic improved both the main outcomes of the intervention, viz. physical function and functional status, and as the secondary outcomes, viz. muscle strength, walking speed and balance, compared to a low-intensity home exercise program comparable to usual care (Binder et al. 2004). Another study showed promising results for home-based physiotherapy, while only six home visits by the physioterapist and nurse improved perceived walking difficulties to the same content as one-month conventional institution-based rehabilitation (Kuisma 2002).

TABLE 1 Home-based multi-component randomized controlled trials among community-dwelling older people.

Multi-component home-based interventions to improve mobility

Reference	Sample	Intervention	Outcome measures for hip fracture patients	Effect	
Crotty et al. 2002 & Crotty et al. 2003	n=66 (34/32) mean 82.5 years 68% women Australia	Started in hospital, duration from early discharge to 4 months, assessments at 4 and 12 months, individually tailored home-based rehabilitation targeting to improve activities of daily living, home environmental modification, modification of assistive devices vs. usual care	Mobility	4-mth	12-mth
			- Timed Up-and-Go (TUG), (Podsiadlo & Richardson 1991)	NS	+
			Balance		
			- Balance confidence (ABC), (Powell & Myers 1995)	NS	NS
			- Functional balance (BBS), (Berg et al. 1992)	NS	NS
			- Fear of falling (FES), (Tinetti, Richman & Powell 1990)	+	
			Modified Barthel Index, (Shah, Vanclay & Cooper 1989)	+	NS
			Quality of life (SF-36), (Ware & Sherbourne 1992)		
			- Physical component	NS	NS
			- Mental component	NS	NS
Latham et al. 2014	n=232 (120/112) mean 78.0 years 69% women USA	Started < 2 years post-fracture (on average 9 months), duration 6 months, assessments at 6 and 9 months, home-based exercise program, with 3-4 home visits by physical therapist, monthly telephone calls and DVD version of the program. Intervention consisted functional tasks, standing exercises, self-efficacy components for fear of falling, goals and exercise calendar vs. control group with nutrition education	Mobility	6-mth	9-mth
			- Physical function (SPPB), (Guralnik et al. 1994)	+	+
			Activity Measure for Post-Acute Care (AM-PAC), (Jette et al. 2007)		
			- Mobility	NS	+
			- Daily activity	+	+
			Strength		
			- Lower extremity strength, fractured side	NS	NS
			- Lower extremity strength, non-fractured side	NS	+
			Balance		
			- Functional balance (BBS), (Berg et al. 1992)	+	+
			- Fear of falling (FES), (Tinetti, Richman & Powell 1990)	NS	NS
			Self-efficacy		
			- Exercise Scale, (Resnick & Jenkins 2000)	NS	+
			- Outcomes Expectations for Exercise Scale, (Resnick et al. 2000)	NS	NS

(continues)

Orwig et al. 2011	n=180 (91/89) mean 82.4 years 100% women USA	Started 3 weeks after hip fracture, duration 12 months, assessments at 2, 6 and 12 months, home-based Exercise Plus program consisted e.g. strength, balance and stretching exercises and a self-efficacy based motivational component vs. usual care	Mobility	12-mth
			- 6-min walk test	NS
			- Physical activity (YPAS), (Dipietro et al. 1993)	+
			- Gait pattern, (Fox et al. 1998)	NS
			Balance	
			- Global balance, (Fox et al. 1996)	NS
			Lower extremity Gain Scale, (Zimmerman et al. 2006)	
			- Lower extremity performance	NS
			- Chair rise time	NS
			- Timed walk	NS
			Grip strength	NS
			PADL (Functional Status Index), (Jette et al. 1987)	NS
			IADL	NS
			Health related quality of life (SF-36), (Ware & Sherbourne 1992)	NS
			Depression (GDS), (Sheikh et al. 1991)	NS
			Bone mineral density (DXA)	NS
Shyu et al. 2010 & Tseng et al. 2012*	n=162 (80/82) mean 78.2 years 69% women Taiwan	Started immediately after hip fracture, duration from fracture to 3 month after discharge, assessments at 1, 3, 6, 12, 18 and 24 months, interdisciplinary program: geriatric consultation, discharge planning: competence, recourses and service need, home environmental modifications, in-hospital and home-based rehabilitation: progressive strength, balance exercises, phone call follow-ups vs. usual care without patient rehabilitation	Mobility	3-mth
			- Walking ability (Barthel Index + performance-based)	+
			Strength	
			- Hip flexion (ROM)	NS
			- Quadriceps strength	+
			Falls	NS
			Self-care ability (CBI)	+
			Health-related quality of life (SF-36), (Ware & Sherbourne 1992)	
			- Physical score	+
			- Mental score	NS
			ADL performance (Barthel index)	+
			Depressive symptoms (GDS-s), (Burke, Roccaforte & Wengel 1991)	+
			Mortality	NS
			Service utilization	NS
			* Better 2-year functional recovery trajectory for intervention	+

(continues)

Tinetti et al. 1999	n=304 (148/156) mean 80.0 years 82% women USA	Started 3.5 months after hip fracture, duration 6 months assessments at 6 and 12 months, systematic multi-component home-based rehabilitation including progressive strength, balance and functional exercises, home environment modifications vs. usual care	Mobility	6-mth	12-mth
			- Walking speed (10-feet x 2)	NS	NS
			- Negotiating stairs	NS	NS
			- Timed sit-to-stand (x 3), (Gill, Williams & Tinetti 1995)	NS	NS
			Balance		
			- Functional balance (BBS), (Berg et al. 1992)	NS	NS
			Strength		
			- Upper extremity strength, non-fractured side	+	NS
			- Lower extremity strength, non-dominant side	NS	NS
			Performance-Oriented Mobility Assessment (POMA), (Tinetti 1986)	NS	NS
			ADL performance	NS	NS
			Social activity (EPESE), (Cornoni-Huntley et al. 1993)	NS	NS
			Depression symptoms (CES-D), (Kohout et al. 1993)	NS	NS
Tsauo et al. 2005	n=25 (13/12) mean 73.0 years 80% women Taiwan	Started at discharge, duration 3 months, assessments at 1, 3 and 6 months, individualized home-based multi-component physical therapy program including e.g. strength, balance and functional exercises vs. in hospital bedside exercises, usual care	Mobility	3-mth	6-mth
			- Walking speed	NS	NS
			Strength		
			- Hip flexor strength	NS	NS
			- Hip extensor strength	NS	NS
			- Hip abductor strength	NS	NS
			- Knee extensor strength	NS	NS
			Hip range of motion	NS	NS
			Functional recovery (Harris hip score), (Harris 1969)	+	NS
			Health-related quality of life (WHOQOL-BREF), (Anonymous1998)	+	NS
Zidén et al. 2008 & Zidén et al. 2010	n=102 (48/54) mean 81.9 years 70% women Sweden	Started at discharge, duration 1 month, assessments at 1, 6 and 12 months, multi-professional home rehabilitation program focused on supported discharge,	Mobility	1-mth	12-mth
			- Sit-to-stand	(+)	(+)
			- Physical mobility (TUG), (Podsiadlo & Richardson 1991)	(+)	(+)
			- Walking several blocks	(+)	(+)
			- Negotiating stairs	(+)	(+)
			Balance		
			- Balance confidence (FES), (Tinetti, Richman & Powell 1990)	+	+

(continues)

	independence in daily activities, and enhancing physical activity and confidence in performing daily activities vs. usual care	Functional independence (FIM), (Keith et al. 1987)	+	+
		IADL independence (IAM), (Grimby et al. 1998)	+	+
		Frequency of social and daily activities (FAI), (Holbrook & Skilbeck 1983)	+	+

+ positive effect for intervention; - no differences between the study groups; (+) difference between the study group by time point, no group by time interaction

3 AIMS OF THE STUDY

The aim of this thesis was to investigate walking recovery and underlying determinants early after discharge home from hospital and to investigate whether musculoskeletal lower body pain and the type of surgical treatment received was associated with mobility limitation and physical inactivity two to three years after a hip fracture. In addition, the effects of an individually tailored multi-component home-based rehabilitation program on mobility disability were studied. This thesis focused on community-dwelling men and women over age 60 who had sustained a hip fracture. The specific aims of this thesis were:

1. To examine whether the type of surgery performed is associated with musculoskeletal pain in the lower body and mobility limitation at, on average, 1.9 years after femoral neck surgery. (Study I)

2. To examine the association between physical inactivity and musculoskeletal pain in the lower body at, on average, 3.3 years after a hip fracture. (Study II)

3. To investigate recovery of ability to walk outdoors within the first ten weeks after a hip fracture and to explore the determinants associated with different walking trajectories after the fracture. (Study IV)

4. To investigate the effects of an individually tailored multi-component home-based rehabilitation program on mobility recovery after a hip fracture. (Studies III & V)

4 METHODS

4.1 Study designs and participants

This study is based on data from two randomized controlled trials: “Muscle strength and power in old age: special emphasis on lower limb asymmetry, morbidity and balance” (Hip-Asymmetry study) and “Promoting mobility after hip fracture” (ProMo study). Both studies investigated health, physical function, and rehabilitation among older people who have sustained a hip fracture. In both studies, the laboratory assessments were performed at the same research center, using the same equipment. In both studies, participants were recruited from the Central Hospital of Central Finland Health Care District applying almost identical inclusion and exclusion criteria. For this thesis, only the baseline data of the Hip-Asymmetry study was used. The study designs and participants are summarized in Table 2.

4.1.1 Hip-Asymmetry study (I, II)

The Hip-Asymmetry study was a randomized controlled trial (IRCTN34271567) investigating the effects of resistance training on lower limb muscle strength, mobility and balance in older men and women with hip fracture history (Portegijs et al. 2009). To identify potential participants, the patient records of hip fracture patients surgically operated in the Central Hospital of Central Finland from 8 months to 7.5 years earlier were reviewed during the years 2004 and 2005. Data were collected in two phases, in 2004 and in 2005 as the number of eligible subjects found in 2004 did not provide a large enough sample. In 2005, the recruitment area was enlarged to include not only the city of Jyväskylä, but also all the municipalities in the Central Finland Health Care District. The target participants were community-dwelling men and women aged 60-85 who had been operated on for a femoral neck or trochanteric fracture and therefore might have had asymmetrical muscle strength deficit in the lower extremities. A letter informing them about the study and inviting them to participate was sent to all patients alive (n=452) and living in the Central Finland Health Care

District. In total, 193 patients responded to the letter and 132 of them expressed initial interest in the study. Patients were interviewed over the telephone to ensure their interest in and suitability for the study. The exclusion criteria were inability to move outdoors without assistance from another person, amputation of a lower limb, severe progressive or neurological diseases and severe memory problems (diagnosed dementia or MMSE<19). Seventy-eight (53 women, 25 men) subjects attended the laboratory examinations. The study flow is presented in Figure 3.

Sample size was calculated for the intervention research framework. The power calculations have based on the results of previous studies (Häkkinen & Häkkinen 1995, Skelton et al. 1995, Sipilä et al. 1996) indicating that three months of strength training increased muscle strength by 15–37% among healthy older women. In the Hip-Asymmetry study, the expected change in muscle strength was therefore set to 25%. The power calculations indicated that a minimum of 30 participants should be included in both study groups (intervention and control) to detect significant changes in the main outcome measures: muscle force, muscle power and balance (α=0.05 and β=0.20, power 80%).

4.1.2 ProMo study (I, III-V)

The ProMo study was a randomized controlled trial investigating community-dwelling men and women aged 60 years and older recovering from a hip fracture (ISRCTN53680197). The staff of the physiotherapy department at the Central Hospital of Central Finland informed the about the study all, ambulatory and community-dwelling men and women over age 60, arriving for surgery for a of femoral neck or trochanteric fracture (ICD code S72.0 or S72.1) between the dates 1.3.2008 and 31.12.2010 and living in the city of Jyväskylä or in its nine neighboring municipalities. In total, 296 patients fulfilled the inclusion criteria and were informed about the study during the inpatient period after their hip fracture surgery. Of these, 161 were interested in participating in the study, and were subsequently visited by a researcher. Finally, 136 persons were recruited to the study. Patients suffering from severe memory problems (MMSE<18), severe depression (BDI-II>29), severe cardiovascular, pulmonary condition or some other progressive disease, or alcoholism were excluded. In total, 81 hip fracture patients participated in the study. The study flow is presented in Figure 4.

TABLE 2 The summary of study designs, analyses and outcomes.

Study	Data	n	Design	Analyse	Main outcome
I	Hip-Asymmetry + ProMo	115	cross-sectional	group comparisons between two and four groups	pain with VAS, perceived walking difficulties, Grimby, 10 m walk, TUG, BBS
II	Hip-Asymmetry	78	cross-sectional	logistic regression analyse	pain with VAS, YPAS
III	ProMo	81	cross-sectional	group comparisons between two groups	study design, demographics, health status, physical characteristics, living habits
IV	ProMo	81	longitudinal	linear latent trajectory model and logistic regression analyse	perceived walking difficulties
V	ProMo	81	RCT	generalized estimation equations and repeated measures mixture path models	muscle power deficit, BBS, SPPB, perceived difficulty in negotiating stairs

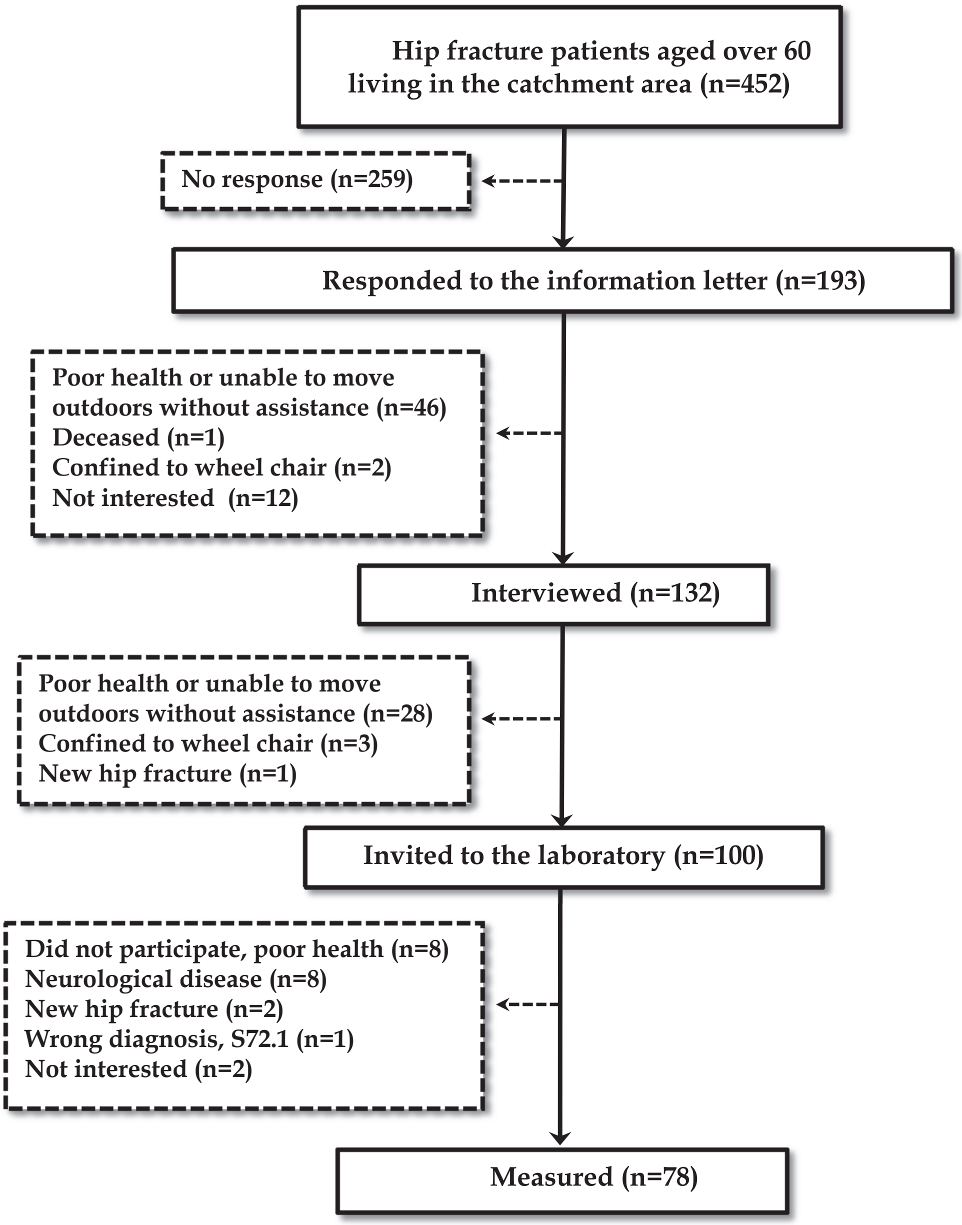

FIGURE 3 The flow chart of the Hip-Asymmetry study.

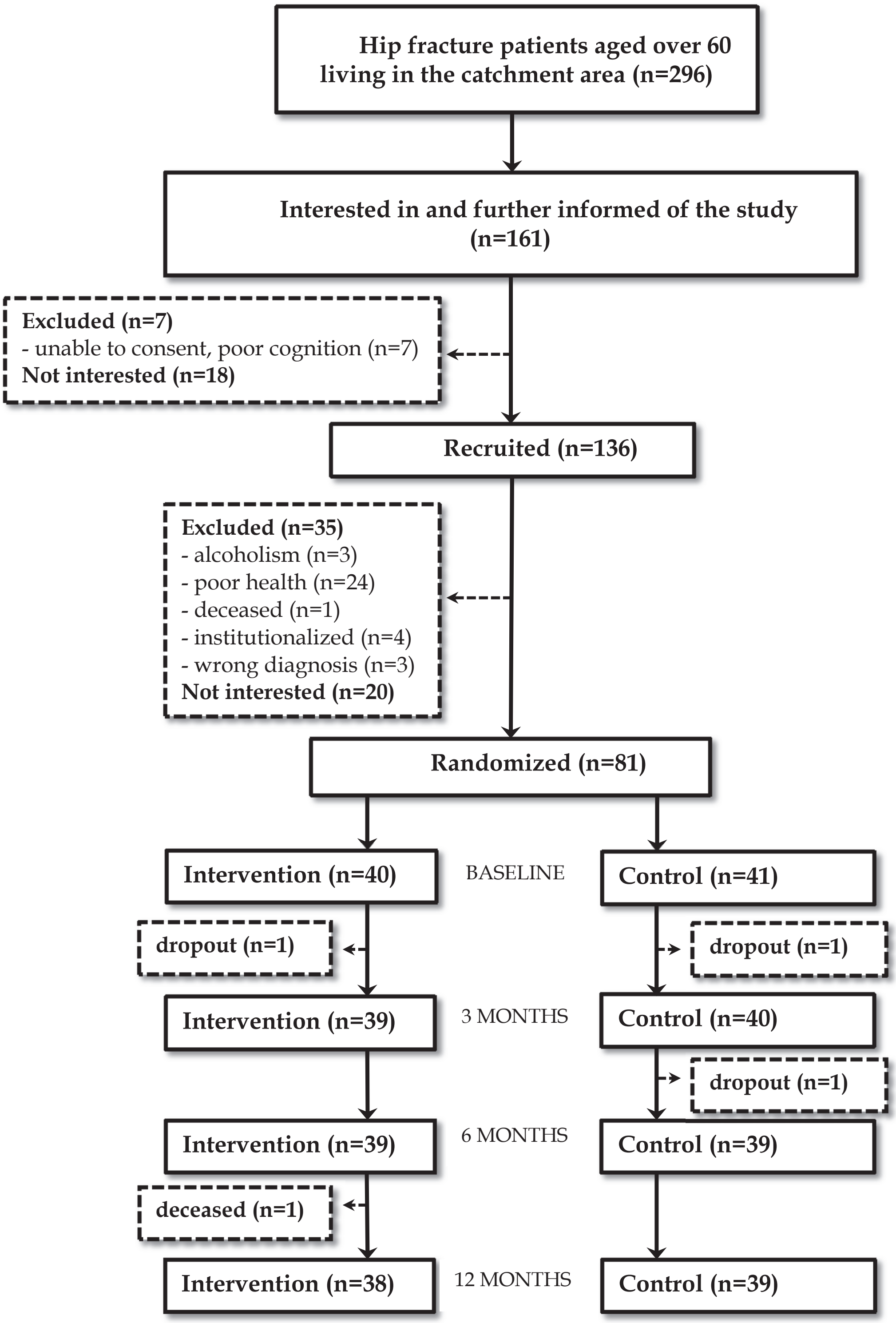

FIGURE 4 The flow chart of the ProMo study.

Baseline measurements were conducted as soon as possible after discharge home from the hospital, on average 9.9±4.0 weeks after the fracture. After the baseline measurements, participants were randomized into the intervention (promoting mobility program, ProMo, and standard care) and control (standard care) groups. Men and women and those operated with internal fixation or arthroplasty were randomized by blocks of 10. Follow-up measurements were organized at 3, 6 and 12 months after the baseline measurements. The same personnel conducted both the baseline and follow-up assessments. The researchers who collected the outcome measures were blinded to the participants´ group allocation. To ensure blinding, participants were asked not to disclose their group allocation to the assessors. The researchers underwent training and followed procedures, as outlined in the study manual.

Sample size. A previously published study of mobility recovery after hip fracture (Visser et al. 2000) was used for the pre-trial power calculations. According to that study, 45.3% of the community-dwelling participants were independent in chair rising, walking one block and negotiating stairs before the fracture. Less than half of the hip fracture patients (20.7% of the total sample) had regained their pre-fracture mobility level a year later. The purpose of our study was to restore participants' pre-fracture level of mobility through the intervention. To detect the expected difference in mobility recovery (based on the percentages of 45.3 and 20.7 observed in the study Visser et al. (2000)) between the study groups for α=0.05 and β=0.20, a minimum of 44 subjects was needed in each study group.

Randomization. A statistician not involved in the recruitment or data collection carried out a computer-generated group allocation list. The study group assignment was sealed in closed envelopes. The random allocation to the intervention and control groups was performed immediately after the baseline measurements. Men and women and those operated with internal fixation or arthroplasty were randomized by blocks of 10.

4.1.3 Pooled data set and reference group (I)

The pooled baseline data from the Hip-Asymmetry and ProMo studies, including only participants with a femoral neck fracture were used in paper I. To assess the associations of the type of surgical method with pain and mobility limitation (I), participants were stratified into internal fixation, hemiarthroplasty and total hip replacement groups. In the analysis, the most recent surgical treatment defined the study group. In addition, reference group matched for age and gender was recruited through advertisements in the catchment area of the same health care district from where the hip fracture participants were recruited (Mikkola et al. 2007). The reference group consisted of 31 community-dwelling older people (25 women, 6 men) without major lower limb injuries or hip or knee replacement surgery within the previous 15 years (Table 4).

4.2 Ethics

The ethical committee of the Central Finland Health Care District approved the study protocols (Hip Asymmetry, Dnro 41/2003 and ProMo, Dnro 56/2007). The studies were conducted in accordance with the Declaration of Helsinki. All participants gave their written informed consent prior to participating in the study and gave to researchers permission to review their medical records. The participants were able to discontinue their participation at any point if they so wished.

4.3 Measurements

All the measurements, along with reliability coefficients and relevant references, are summarized in Table 3. The main assessments are presented first, followed by descriptive variables and covariates.

4.3.1 Mobility limitation

Performance-based assessments. During all the performance-based mobility tests, the use of a walking aid commonly used for walking indoors was allowed. Participants were instructed to do the tests as fast as possible, without compromising their safety. Maximal walking speed on 10 meters (I) was assessed in a laboratory corridor. The participants were allowed three meters for acceleration. The faster performance of two trials was used in the analysis. Time was measured using photocells. The Timed Up-and-Go-test (TUG) measures the time that it takes to rise from a chair, walk 2.44 meters, circle around a cone and return to the chair (Podsiadlo & Richardson 1991) (I). The test was performed twice and the fastest result was used in the analysis. The Short Physical Performance Battery (SPPB) includes habitual walking speed, chair rise and balance tests (Guralnik et al. 1994) (V). The maximum score is 12, and a higher score indicates better performance. The SPPB is a validated and often-used measurement among older people for predicting falls and loss of independence (Guralnik et al. 1994).

Self-reported walking difficulties. Perceived walking difficulties due to the hip fracture (I) was assessed with the question "Have you had walking difficulties due to your hip fracture during the last week/month"? The week/month in was the last week for those with the most recent surgery from six weeks to six months earlier (ProMo study), and the last month, for those with the most recent surgery more than 6 months earlier (Hip-Asymmetry study). The response options were 1) no difficulties, 2) some difficulties, 3) quite a lot of difficulties, and 4) a lot of difficulties. The options were then dichotomized into yes (3,4) and no (1,2).

Perceived change in mobility after a hip fracture (I) was assessed with the question "Has your mobility changed since your a hip fracture?". The response options were 1) no change, 2) yes, mobility is better, and 3) yes, mobility is worse.

TABLE 3 Summary of the measurement methods and variables used in this thesis including references and reliability.

Measurements	Study	Methods and reference	Reliability and reference
Mobility limitation, performance-based assessments			
Maximal walking speed, 10 meters (s)	II	Photocells	CV 5% (Rantanen & Avela 1997)
Physical performance (s)	II	Timed Up-and-Go-test (TUG) (Podsiadlo & Richardson 1991)	ICC=0.97 (Steffen, Hacker & Mollinger 2002)
Physical performance (score)	V	Short Physical Performance Battery (SPPB) (Guralnik et al. 1994)	ICC=0.83–0.89 (Freire et al. 2012)
Mobility limitation, self-report			
Walking difficulties (cat)	II	Self-reported questionnaire	
Deterioration in mobility (cat)	II	Self-reported questionnaire	
Walking difficulties outdoors (cat)	IV	Self-reported questionnaire	
Walking difficulties in 500 meters (cat)	IV	Self-reported questionnaire	
Walking difficulties at the ward (cat)	IV	Self-reported questionnaire	
Difficulties in negotiating stairs (cat)	V	Self-reported questionnaire	
Use of walking aids indoors/outdoors (cat)	II, IV, V	Self-reported questionnaire	
Musculoskeletal pain			
Low back, hip or knee, both sides (cat)	I	Visual Analog Scale (Huskisson 1974)	ICC=0.95-0.98 (Bijur, Silver & Gallagher 2001)
Hip and knee, both sides (mm)	II	Visual Analog Scale (Huskisson 1974)	ICC=0.95-0.98 (Bijur, Silver & Gallagher 2001)
Low back, hip or knee, both sides (mm)	IV, V	Visual Analog Scale (Huskisson 1974)	ICC=0.95-0.98 (Bijur, Silver & Gallagher 2001)
Offending pain, fractured side (cat)	IV	Self-reported questionnaire	
Muscle strength			
Maximal isometric knee extension force, both sides (N)	I, IV	Dynamometer	CV 6% (Sipilä et al. 1996)
Leg extension muscle power (W)	V	Leg extensor Power Rig	CV 8% (Tiainen et al. 2005)
Functional balance	V	Berg Balance Scale, BBS (Berg et al. 1992)	ICC=0.97 (Berg, Wood-Dauphinee & Williams 1995)

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Balance confidence	I	Activities-specific Balance Confidence scale (Powell & Myers 1995)	ICC=0.92, α=0.96 (Powell & Myers 1995)
Physical activity			
Physical activity (score)	I	Yale Physical Activity Survey (Dipietro et al. 1993)	ICC=0.44-0.99 (Kolbe-Alexander et al. 2006)
Physical activity (cat)	II	Scale of Grimby, modified (Grimby 1986)	
Demographics and health status			
Age (years)	I-V	Medical records	
Sex (cat)	I-V	Medical records	
Presence of chronic conditions (n)	I-V	Medical examination and medical records	
Use of prescription medication (n)	I-III	Medical examination and medical records	
Fracture date and status (cat)	I-V	Medical records	
Surgery date and type (cat)	I-V	Medical records	
C-reactive protein (hCRP)	III, V	Blood count	
Hemoglobin level (g/l)	III, V	Blood count	
Blood pressure (mmHg)	V	Digital sphygmomanometer	
Cognitive status (score)	I-V	Mini-Mental State Examination (Folstein, Folstein & McHugh 1975)	α=70 (Lopez et al. 2005)
Depressive mood (score)	I-V	Beck Depression Inventory (Beck et al. 1996)	α=0.90 (Storch, Roberti & Roth 2004)
Antropometry			
Body weight (kg)	I-V	Beam scale	
Body height (cm)	I-V	Scale stadiometer	
Body mass index (kg/m2)	I-V	Calculated, (body weight):(body height)^2 x 100	
Body composition, fat free mass (kg)	I	Bioimpedance	CV 3% (Volgyi et al. 2008)
Falls indoors/outdoors (cat)	IV	Self-reported questionnaire	

α=Cronbach´s alpha; CV%=coefficient of variation; ICC intraclass correlation coefficient

Difficulties in walking outdoors and 500 meters (IV) were assessed by a questionnaire. The questions were formulated as “Do you have difficulty in walking outdoors/500 meters?” with the response options 1) able to manage without difficulty, 2) able to manage with some difficulty, 3) able to manage with a great deal of difficulty, 4) able to manage only with the help of another person, and 5) unable to manage even with help. For the analyses, options 4 and 5 were combined due to the low response frequencies in the latter category. In the ProMo study, the measurements were carried out pre-fracture elicited at the hospital on average 10±5 days post-fracture, at discharge from the hospital or health care center, and 6±3 weeks after discharge to home.

Perceived difficulty in walking in the hospital ward (IV) was assessed with the question “How well do you manage in moving around in the ward?” The response options were 1) able to manage without difficulty, 2) able to manage with some difficulty, 3) able to manage with great deal of difficulty, 4) able to manage only with the help of another person, and 5) unable to manage even with help. For the analyses, the options were dichotomized into “no difficulty” (1) and “difficulty” (2-5).

Mobility-related disability was assessed by perceived difficulties in negotiating stairs (V). In the study, the participants were asked “Are you able to negotiate one flight of stairs (five stairs)?” The response categories were 1) able to manage without difficulty, 2) able to manage with some difficulty, 3) able to manage with lots of difficulty, 4) able to manage only with the help of another person, and 5) unable to manage even with help.

Use of walking aids indoors and outdoors (I, IV, V) were elicited separately with the question “Do you use walking aid indoors/outdoors in everyday life?” The response options were “yes”, “no” and “I don’t walk outdoors”. Use of walking aids during the previous year before the hip fracture was collected during the inpatient period (IV). Participants who reported not walking outdoors were categorized as using a walking aid outdoors (V).

4.3.2 Musculoskeletal pain

Pain in the lower back, hip or knee region on both sides of the body during the last week was assessed with the Visual Analog Scale (VAS, studies II and IV, V). In paper I, musculoskeletal pain was assessed in four regions; both hips and knees. The 100-mm-long VAS line was used without numbers. The left end of the line (0 mm) represents “no pain” and the right end (100 mm) “the worst imaginable pain” (Huskisson 1974). A summary index was calculated from all the measured VAS variables. In the reference group (I), the mean VAS value of both sides was calculated and used for analysis. In study II, musculoskeletal pain was dichotomized into severe pain (pain 66 mm or above in at least one of the six body regions assessed) and less or no pain (pain below 66 mm).

In addition, moving-related pain (IV) on the fractured side at the time of discharge from the hospital was assessed with the question “Do you have offending pain in the low back/hip/knee on the fractured side which impairs your moving?” Pain was considered moving-related, if it affected moving in at least one of the measured body regions.

4.3.3 Muscle strength

Maximal isometric knee extension force (Newton, N) was measured in the fractured and non-fractured leg using an adjustable dynamometer chair (Good Strength, Metitur LTD, Palokka, Finland) (II, IV). For all participants, the non-fractured leg was assessed first. The ankle was attached to a strain gauge with the knee angle fixed at 60 degrees from full extension. The leg was extended as forcefully as possible and participants were encouraged to make a maximal effort during the measurement. The contraction was maintained for 2-3 seconds. The rest period between the trials was 30 seconds. The measurement was repeated at least three times, until no further improvement occurred. The best performance was used in the analysis.

Leg extension muscle power (Watt, W) was measured with the Nottingham Leg Extensor Power Rig (Portegijs et al. 2009, Bassey & Short 1990) and the non-fractured leg was assessed first (V). The seat was adjusted for the length of the legs. The measurement was repeated until no further improvement occurred and the best performance was used in analysis. Asymmetrical leg extension power deficit between legs was calculated according to the formula: *LEP non-fractured leg - LEP fractured leg*. Leg extension power is a valid measurement and has been found to be safe among older people (Bassey & Short 1990).

4.3.4 Functional balance and balance confidence

Functional balance was assessed by the Berg Balance Scale (BBS), which evaluates an individual´s ability to perform different tasks related to the skills of sitting down, standing up, reaching, turning around, looking over one´s shoulder, and one-foot standing (Berg et al. 1992) (V). The ability to perform each of the 14 tasks is rated from 0 (incapable) to 4 (safe and independent). The maximum score is 56, with higher scores indicating better functional balance.

Balance confidence (I) was assessed with the Activities-specific Balance Confidence scale (ABC), which measures confidence in carrying out specific activities without falling or becoming unsteady (Powell & Myers 1995). The scale consists of 16 items in which subjects are asked to report their confidence in their ability to keep their balance when performing different activities, including activities outside the home. All answers are rated from 1 (no confidence) to 10 (total confidence). The ABC summary scale ranges from 16 to 160, a small value indicating poor balance confidence.

4.3.5 Physical activity

The Yale Physical Activity Survey (YPAS) was use to assess physical activity in the Hip-Asymmetry study (II). The YPAS is an interview, which was specifically developed to assess physical activity in the older population (Dipietro et al. 1993). The YPAS comprehensively describes overall physical activity and also provides information on whether the activities reported are light or moderate in intensity (Resnick et al. 2008). A physical activity dimension summary index, which is the sum of five weighted subindices, can be calculated from the YPAS. Participants were asked how many times they performed vigorous physical activity (weighting of 5) and leisure walking (weighting of 4) during the past month and the duration of each physical activity session. The frequency, duration score and weighting of each respective activity were multiplied. Additionally, participants were asked to estimate how much time they spent moving around indoors and outdoors (weighting of 3), standing (weighting of 2) and sitting (weighting of 1) on an average day in the past month. The duration score for an activity was multiplied by its weighting. For the data analysis, participants were first divided into physical activity tertiles according to the YPAS summary index distribution: low, middle and high. In order to explore in more detail the most physically inactive subjects, the lowest tertile was compared to the combined middle and high physical activity group.

In addition, physical activity was assessed with a modified version of the scale of Grimby (Grimby 1986) (I). The questionnaire includes seven response categories for activity level: 1) mainly resting, 2) most activities performed sitting down, 3) light physical activity twice a week at the most, 4) moderate physical activity about 3 hours a week, 5) moderate physical activity at least 4 hours a week or heavy physical activity over 4 hours a week, 6) physical exercise or heavy leisure time activity several times a week, and 7) competitive sports several times a week. For the analysis, participants were categorized as sedentary (categories 1-3) or moderate to active (4-7).

4.3.6 Descriptive variables and covariates

Demographics and health status. Age and gender were confirmed from the medical records. During a medical examination, a nurse and a physician confirmed the presence of chronic conditions, use of prescription medication, fracture date and status, and type and date of surgery according to a pre-structured questionnaire, current prescriptions and medical records obtained from the local hospital and health care centers. Contraindications for participation in the physical performance assessments were evaluated by a physician (American College of Sports Medicine 2010) and acute conditions (e.g. acute respiratory or urinary tract infection) by blood count, C-reactive protein (hCRP) and hemoglobin (Hb) analysis. Blood pressure (mmHg) measured with digital sphygmomanometer. Cognitive status was assessed by the Mini Mental State Examination (MMSE) which is 30-point questionnaire (Folstein, Folstein & McHugh 1975), and depressive mood by the Beck Depression Inventory (BDI-II) consisting on 21 questions on the severity of depression (Beck et al. 1996).

Anthropometry. Body weight and height were measured, and body mass index calculated as weight (kg) divided by height (m) squared. Fat-free mass was assessed using a computerized single-frequency bioimpedance device (BC-418; Tanita Corp., Tokyo, Japan) using the manufacturer's equation (II). During the measurements, participants were instructed to stand still on a scale platform barefoot while holding the handgrips.

Falls. Pre-fracture falls indoors and outdoors were collected retrospectively with a questionnaire (IV). The questions were formulated as "How often have you fallen indoors/outdoors during the year before the hip fracture?" with the response options 1) no falls, 2) once, 3) 2-4 times, 4) 5-7 times, and 5) 8 times or over. Falls were dichotomized as "no falls" and "one or more falls".

4.4 The ProMo individually tailored multi-component home-based rehabilitation program

Standard care (III-V). All participants received standard care after discharge from hospital or the health care center. At baseline, information on standard care after the hip fracture was collected by interview. Seventy per cent of all participants received a written home exercise program with no difference between the intervention and control groups (68% vs. 71%, p=0.813, respectively). The program usually included five to six exercises, including ankle flexion/extension, knee flexion/extension, and hip abduction/extension in the supine, sitting and/or standing positions with no additional resistance. None of the participants were followed up for compliance with the home exercises and the program was not updated.

ProMo rehabilitation. Participants in the intervention group received standard care and a ProMo rehabilitation program aimed to restore mobility after a hip fracture. ProMo was an individually tailored yearlong physical activity and rehabilitation intervention, which took place in the participants' homes. It began on average within one week of the baseline measurements and included five to six home visits by a physiotherapist. Figure 5 presents the protocol schedule of the ProMo intervention.

During the first face-to-face session, a physiotherapist evaluated environmental hazards for falls and gave instructions and guidance for safe walking (Mänty et al. 2006). Participants' falls related to self-efficacy, their satisfaction with and usability of walking aids, and the potential benefits of hip protectors were also discussed. In addition, an individual non-pharmacological pain management evaluation took place in the second face-to-face session and was repeated at three and six months. During the pain management sessions, data on the location and duration of offending musculoskeletal pain was collected by a structured interview and the participant´s knowledge of pain relief strategies was discussed (Barry et al. 2005). The first and second home visits were intended to prepare the ground for the home exercises and physical activity.

During the second home visit, an individual 30-minute progressive home exercise program comprising strengthening and stretching exercises for the lower limb muscles, balance training and functional exercises was implemented. It was updated four to five times with a more intensive and demanding protocol. The first update occurred after one week of training, during the third home visit. The updated programs were delivered after one (fourth home visit), three (fifth home visit), six (sixth home visit), and nine months (phone call). The functional exercises included walking, reaching/turning in different directions, and stair climbing. The strengthening exercises included knee extension and flexion, hip abduction, plantar flexion, chair rising, and squatting. Progression in the knee extension and flexion and hip abduction exercises was increased with resistance bands of three different strengths. The standing balance exercises included weight shifting, stepping forward, to the side, and backwards, and standing on one leg. The level of challenge was increased during the training period by reducing hand and base of support. The strengthening and stretching exercises were advised to be done three times a week on the same day. The balance, walking and functional exercises were to be done two to three times a week on the same day. The expected number of exercises during the one-year intervention was 316 (strengthening and stretching exercises three times a week, balance exercises two to three times a week and functional exercises two to three times a week for the first twelve weeks). All participants kept a daily exercise diary on home exercises. If the diary was not returned on time the physiotherapist reminded the participant by telephone.

All participants kept a daily exercise diary, which was mailed to the research physiotherapist monthly. If the diary was not returned on time the physiotherapist reminded the participant by telephone.

Individual motivational face-to-face physical activity counseling took place after three months (fourth home visit) in the participants' homes (Rasinaho et al. 2012). Counseling was delivered as a one-off session followed by phone calls at four and eight months, and a face-to-face meeting at six (sixth home visit) months to promote and encourage participants to engage in physical activity.

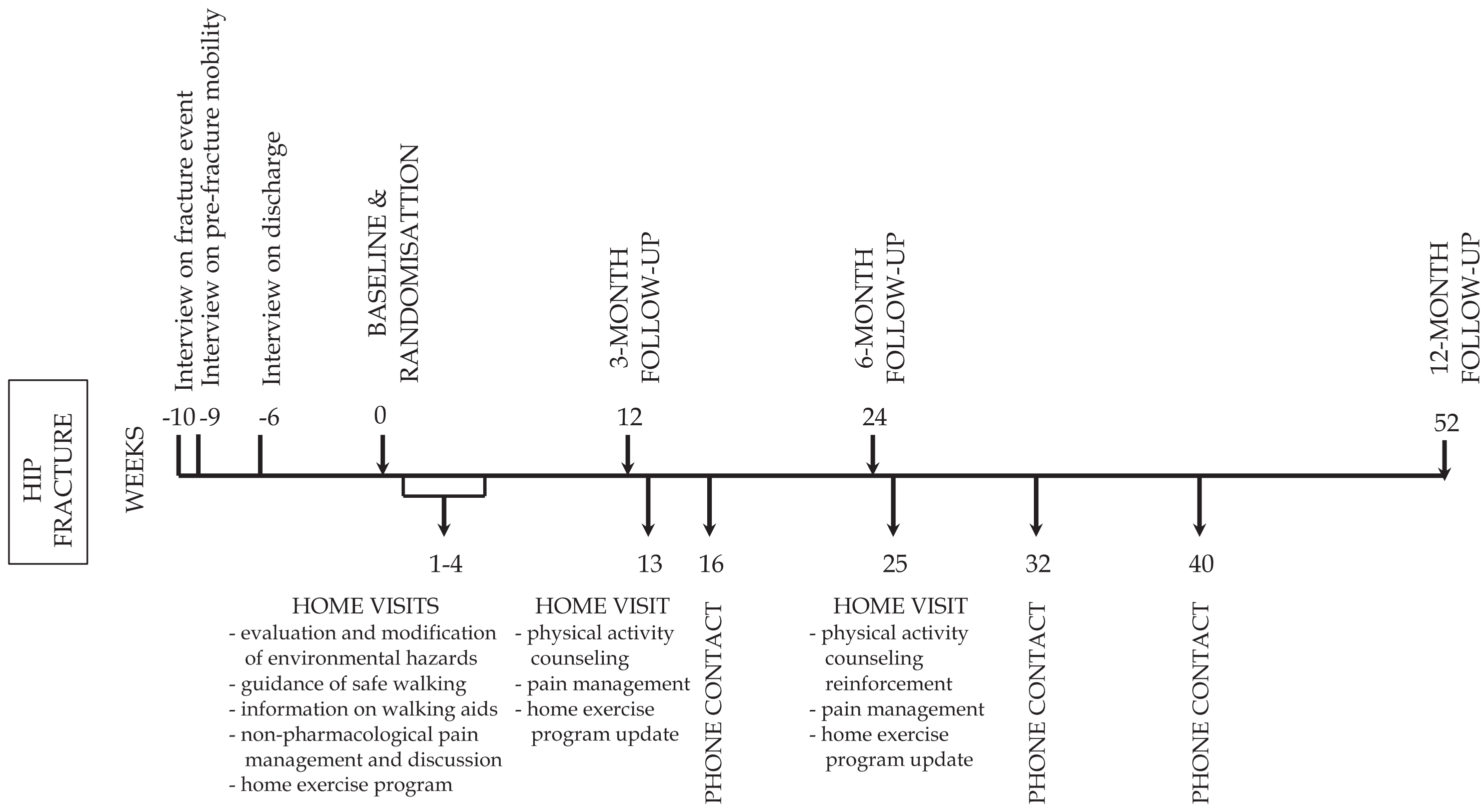

FIGURE 5 The timetable of ProMo intervention and follow-up measurements and intervention.

4.5 Statistical methods

Basic descriptive statistics and group comparisons (I-V). Means, medians and standard deviations were calculated for continuous variables. Normality of the continuous variables was tested with the Kolmogorov-Smirnov test and Shapiro-Wilk test. For the normally distributed variables, independent samples T-test was used to compare the means and medians of the two study groups and One-Way ANOVA (II) was used to compare the means of more than two groups. Differences between the two groups in non-normally distributed variables were tested with the Mann-Whitney U test and for more than two group comparisons with the non-parametric Kruskal-Wallis H test (II). Differences between the study groups for the non-normally distributed variables were tested with a nonparametric Mann-Whitney U test or median test and normally distributed variables with T-test. Differences between the groups in discrete variables were analyzed with the Pearson χ^2 test. All analyses in the RCT setting (V) were performed according to the intention-to-treat principle, meaning that the participant remains the same group from randomization to the end of the study. Compliance with the intervention (V) was calculated using the formula: [amount of performed exercises]:[expected number of exercises] × 100. A *p*-value of <0.05 was considered statistically significant.

Logistic regression modeling (I, IV). Logistic regression modeling was used to determine odds ratios (ORs) and 95% confidence intervals (CI 95%) for pain as a predictor of physical inactivity (I) and to find determinants associated with walking trajectories (IV). The model was first adjusted with each determinant one at the time. The final model was adjusted for all determinants (I) or all the determinants, which differed significantly in the one-by-one analysis (IV). Initially, the models (I, IV) were adjusted for age and gender. To retain the statistical power of the final model in paper I, age and gender were not included in the final model.

Linear latent trajectory modeling (IV). The growth mixture model was used for the trajectory analysis. A mixture model includes two (or more) latent groups, whose trajectory parameters are estimated simultaneously together with each individual's probabilities of belonging to these groups. Membership probabilities can be used to describe the clarity of differences between the two groups via the summary statistic entropy, which ranges between zero and one, where a value close to one indicates an unambiguous grouping (Muthen et al. 2002). Within the latent subgroups a growth model was fitted to the data while allowing the model growth parameters to vary over the latent groups. Within latent class g (g=1,2), the (scaled) threshold structure of the response variables within time point I (i=1,…,3) and response category j (j=1,…,3) was modeled as:

$$y_{(G)ij} = \mu_G + 0.1c_i\beta_1 + (0.1c_i)^2\beta_2 + c_j b_{ij}\tau_i,$$

where μ is the grand mean, and β_1 and β_2 are the linear and quadratic growth coefficients, respectively. The coefficient τ describes the separation of the categories within the time points, and we permitted the separation to vary according to time by estimating a threshold-specific factor *b*. At the first time point, *b* was fixed to one for the first response category within the latent groups to establish this as the reference category. The design vector c = (-1,0,1) represents the time point-specific contrast. This model structure enables the structure of the trajectories to be separated into growth parameters, both linear and quadratic, as well as other types of differences in the response probabilities, which are referred to as non-linear in the analysis. The maximum likelihood estimator used in the analyses permitted retaining the participant in the analysis, if there was a non-missing measurement from at least one time point.

Generalized estimating equations (V). The effect of the intervention on the single outcome measures (BBS, SPPB, perceived difficulty negotiating stairs) was assessed using general estimating equations (GEE) models with interaction terms (group x time) assuming an unstructured correlation matrix for the intra-individual repeated measures. In a case of missing data, the GEE methodology uses maximum-likelihood estimation (MLE), which provides estimates for the model's parameters by finding parametric values that make the observed results the most probable.

Mixture path modeling (V). A two-group path model based on a modification of the cross-lagged panel design was constructed to analyze mobility recovery with the hypothesized causal paths between impairment (LEP deficit), functional limitation (SPPB and BBS) and disability (perceived difficulty negotiating stairs). The models were adjusted for age and number of chronic diseases, which are known risk factors for poor mobility recovery after hip fracture. The path modeling strategy avoids the problem of multiple testing related to an approach where each pathway is separately examined. We assumed that, after hip fracture, the acute recovery phase would be similar in both groups. After three months of the ProMo intervention, we expected the pathway observed in the intervention group to be different from that among the controls. The same model was estimated for the intervention and control groups, but with different path coefficients. The assumption was that the power deficit at baseline and 3 months would be associated with functional balance and physical performance at 3 and 6 months, which in turn would be associated with perceived difficulties in negotiating stairs at 6 and 12 months. In addition, pathways from each variable to their respective measures in the following wave was added to the model (LEP deficit, baseline → LEP deficit, 3mth; functional balance, 3mth → functional balance, 6mth; negotiating stairs, 6mth → negotiating stairs, 12mth) to separate the amount of the variance in each variable due to the previous measurements. In addition, the model enabled a direct pathway from level of impairment (LEP deficit) to level of disability (negotiating stairs).

Statistical software. All analyses were performed in study I using SPSS for Windows software version 15.0 (SPSS Inc., Chicago, Illinois), in study II using PASW Statistics for Windows 18.0 and in study III IBM SPSS Statistics for Windows 19.0 (SPSS Inc., Chicago, Illinois). In study IV the trajectory models were analysed with the Mplus-program (version 6; Muthén & Muthén 2011). Descriptive statistics and group comparisons were conducted using the R-environment (version 2.12.2; R Development Core Team 2011). The χ^2 tests of independence were performed using the R-package gmodels (version 2.15.1) and logistic regression with IBM SPSS Statistics for Windows (version 19.0; Armonk, NY:IBM Corp.). In study V descriptive statistics and group comparisons were conducted using IBM SPSS Statistics for Windows (version 19.0; Armonk, NY:IBM Corp.). The path models were analysed with Mplus (version 6; Muthén & Muthén 2011).

5 RESULTS

5.1 Characteristics of the participants

The baseline characteristics of the participants are summarized in Table 4. The majority of the participants were women (68-81%). The participants in the ProMo study were few years older than in the Hip-Asymmetry study and pooled data set, and the reference group without previous hip fracture (Study I) had the youngest mean age. The baseline measurements in the Hip-Asymmetry study were conducted on average 3.3 years and in the ProMo study ten weeks after the hip fracture. Time since fracture in the pooled data set was on average 1.9 years.

Twenty-six percent of the participants were received internal fixation, 61% with hemiarthroplasty and 13% total hip replacement. Participants with hemiarthroplasty were significantly older than those in the other study groups (Table 5). The proportion of women in internal fixation group was lower than in total hip replacement or reference groups. No significant differences were observed in the number of chronic diseases, prevalence of knee or hip osteoarthritis or pain medication between any surgical treatment groups or reference group. Time since latest surgery was significantly shorter among total hip replacement participants compared to the internal fixation and hemiarthroplasty groups. This was due to the number of revision operations in the internal fixation and hemiarthroplasty groups as there were no differences in the time since hip fracture between the groups. Of those with internal fixation as the initial fixation type, 26% had undergone a revision operation (four revised with hemiarthroplasty, one with total hip replacement and in four patients screws were removed). In the hemiarthroplasty group 11% had a revision arthroplasty (four with hemiarthroplasty and three with total hip replacement). None of the participants with a total hip replacement had had a revision operation.

The participants in the Hip-Asymmetry study (II) were stratified according to their level of physical activity and musculoskeletal pain (Table 6).

Groups were comparable in age, gender, height, weight, health status, and fracture type, time since fracture and knee extension strength.

Studies III, IV and V utilize data from the ProMo study. The characteristics of the participants stratified by walking trajectories (IV) are presented in the Table 7. Two trajectories were identified with linear latent trajectory modeling, categorizes participants into two study groups: Catastrophic and No-to-minor-difficulty. No statistically significant difference was observed in age, height, weight, and number of chronic diseases, fracture type, surgical method or gender between the participants in the Catastrophic and No-to-minor-difficulty trajectories. In walking 500 meters ten (19%) of the participants in the Catastrophic trajectory group had osteoarthritis compared to none in the No-to-minor-difficulty trajectory group (p=0.017).

The baseline characteristics of the participants in the ProMo rehabilitation and control groups are presented in Table 8 (III, V). The groups were comparable in all the baseline variables: age, gender, anthropometry, health, fracture and surgery types, balance, strength and mobility.

TABLE 4 Summarized characteristics of participants in the data sets used in the thesis.

	Hip-Asymmetry n = 78	**ProMo n = 81**	**Pooled data (Hip-Asymmetry+Promo) n = 115**	**Reference group (without hip fracture) n = 31**
Age (years)	75.2 ± 6.7	80.0 ± 7.1	76.7 ± 7.0	73.4 ± 6.5
Women	53 (68)	63 (78)	81 (70)	25 (81)
Body height (cm)	164 ± 9	161 ± 9	163 ± 9	161 ± 9
Body weight (kg)	71.0 ± 12.2	65.8 ± 11.5	69.5 ± 11.8	72.6 ± 11.8
BMI (kg/m^2)	26.5 ± 4.1	25.4 ± 3.8	26.1 ± 3.8	27.9 ± 3.7
Number of chronic diseases	3.2 ± 2.0	3.3 ± 1.7	3.3 ± 1.9	3.7 ± 1.9
Osteoarthritis	20 (26)	10 (12)	21 (18)	12 (39)
Hemoglobin (g/L)	129.9 ± 11.9	128.7 ± 12.9	129.1 ± 12.3	138.7 ± 12.1
Time since fracture (years/weeks)	3.3 ± 2.0 years	9.9 ± 4.0 weeks	1.9 ± 2.1 years	-
Fracture type				
Femoral neck, S72.0	63 (81)	52 (64)	115 (100)	-
Trochanteric, S72.1	15 (19)	29 (36)	-	-
Type of surgery				
Internal fixation	36 (46)	38 (47)	30 (26)	-
Hemiarthroplasty	37 (47)	33 (41)	70 (61)	-
Total hip replacement	5 (6)	10 (12)	15 (13)	-

Continuous variables are presented as mean ± SD and categorical variables as n (%).

TABLE 5 Characteristics of participants in pooled data (I) stratified by the surgical method used; internal fixation (IF), hemiarthroplasty (HA), total hip replacement (THR) and reference (REF) groups.

	IF n = 30	**HA** n = 70	**THR** n = 15	**REF** n = 31	**Statistically significant difference between groups, *p***
Age (years)	72.9 ± 7.7	79.4 ± 5.4	71.5 ± 5.7	73.4 ± 6.5	HA-RF(<*0.001*), IF-HA(<*0.001*), HA-THR(<*0.001*)
Women	17 (57)	51 (73)	13 (87)	25 (81)	IF-RF(*0.043*), IF-THR(*0.044*)
Body height (cm)	166 ± 8	162 ± 10	162 ± 5	161 ± 9	IF-RF(*0.033*), IF-HA(*0.029*)
Body weight (kg)	73.5 ± 11.4	68.0 ± 12.2	68.3 ± 8.6	72.6 ± 11.8	IF-HA(*0.034*)
BMI (kg/m²)	26.6 ± 3.8	25.8 ± 3.9	26.1 ± 3.5	27.9 ± 3.7	HA-RF(*0.013*)*
Number of chronic diseases	2.8 ± 1.9	3.5 ± 1.9	2.9 ± 1.8	3.7 ± 1.9	-
Osteoarthritis, hip	2 (7)	3 (4)	2 (13)	2 (6)	-
Osteoarthritis, knee	4 (13)	12 (17)	1 (7)	7 (23)	-
Time since fracture (years)	2.5 ± 2.5	1.8 ± 2.0	1.5 ± 1.9	-	-
Time since last surgery (years)	2.2 ± 2.4	1.6 ± 1.9	0.6 ± 1.0	-	IF-THR(*0.003*), HA-THR(*0.026*)
Prescribed pain medication	12 (40)	32 (46)	8 (53)	8 (26)	-
Lower body pain (VAS, 0-400)	109 ± 81	76 ± 94	47 ± 49	25 ± 39	IF-HA(*0.008*), IF-THR(*0.005*), IF-RF(<*0.001*), HA-RF(*0.024*)
Physical activity, sedentary	5 (17)	14 (20)	2 (13)	0 (0)	IF-RF(*0.018*), HA-RF(*0.007*), THR-RF(*0.038*)
Walking difficulties	16 (53)	20 (29)	2 (13)	-	IF-HA(*0.018*), IF-THR(*0.010*)
Walking aid, indoors	8 (27)	28 (40)	3 (20)	0 (0)	IF-RF(*0.002*), HA-RF(<*0.001*), THR-RF(*0.010*)
Walking aid, outdoors	12 (40)	54 (77)	7 (47)	2 (6)	IF-RF(*0.002*), HA-RF(<*0.001*), THR-RF(*0.001*), IF-HA(<*0.001*), HA-THR(*0.017*)
10 m walking, max (m/s)	1.5 ± 0.5	1.2 ± 0.4	1.3 ± 0.4	1.9 ± 0.3	IF-RF(<*0.001*), HA-RF(<*0.001*), THR-RF(<*0.001*), IF-HA(*0.001*),
Timed Up and Go test (s)	9.4 ± 6.4	13.8 ± 8.2	11.5 ± 4.4	6.3 ± 1.4	IF-REF(*0.001*), HA-RF(<*0.001*), THR-RF(<*0.001*), IF-HA(<*0.001*), IF-THR(*0.018*)
Functional balance (BBS, 0-56)	49.9 ± 5.2	42.8 ± 9.9	48.6 ± 5.3	52.9 ± 3.4	IF-RF(*0.020*), HA-RF(<*0.001*), THR-RF(*0.001*), IF-HA(<*0.001*), HA-THR(*0.012*)

Continuous variables are presented as mean ± SD and categorical variables as n (%).
**p*-value for continuous variables from T-test (otherwise continuous variables analyzed with Mann-Whitney U test and discrete variables with the Pearson χ^2 test).

TABLE 6 Characteristics of participants in Hip-Asymmetry study (II) stratified by physical activity and pain groups. Inactive was defined as lowest tertile in YPAS summary score and Active as combined middle and high tertiles. Musculoskeletal pain in the lower extremities assessed with VAS was defined as Severe pain if it was 66 mm or over (upper third of the scale) and pain below 66 mm was rated as less or no pain.

	Physical activity			**Musculoskeletal pain**		
	Inactive n = 26	**Active n = 51**	***p***	**Severe pain n = 33**	**Less or no pain n = 45**	***p***
Age (years)	75.0 ± 7.5	75.3 ± 6.4	*0.953*§	74.6 ± 7.7	75.7 ± 5.9	*0.804*§
Women	19 (73)	33 (65)	*0.458*	25 (76)	28 (62)	*0.206*
Body height (cm)	162 ± 10	164 ± 9	*0.134*§	162 ± 9	165 ± 9	*0.063*§
Body weight (kg)	71.1 ± 14.2	70.9 ± 11.4	*0.945*	73.7 ± 12.3	69.2 ± 12.0	*0.136*
BMI (kg/m^2)	27.1 ± 5.1	26.2 ± 3.5	*0.457*§	28.1 ± 4.4	25.4 ± 3.5	*0.024*§
Number of chronic diseases	3.8 ± 2.1	2.9 ± 1.8	*0.099*§	3.2 ± 1.9	3.3 ± 2.1	*0.725*§
Osteoarthritis	5 (19)	15 (29)	*0.335*	11 (33)	9 (20)	*0.183*
Time since fracture (years)	2.8 ± 1.8	3.6 ± 2.1	*0.140*§	3.6 ± 2.2	2.9 ± 1.8	*0.184*§
Fracture type, femoral neck, S72.0	22 (85)	41 (80)	*0.650*	23 (70)	37 (82)	*0.704*
Type of surgery			*0.692*			*0.083*
Internal fixation	12 (47)	21 (42)		19 (58)	17 (38)	*0.083*
Arthroplasty	14 (53)	30 (58)		14 (42)	28 (62)	
Severe musculoskeletal pain	16 (62)	16 (31)	*0.011*	-	-	
Prescribed pain medication	9 (35)	13 (25)	*0.402*	16 (49)	7 (16)	*0.002*
Balance confidence (ABC, 16-160)	80.4 ± 35.1	102.2 ± 31.1	*0.007*	82.9 ± 36.1	103.0 ± 30.1	*0.010*
Knee extension force, fractured (N)	206.9 ± 79.3	259.1 ± 114.4	*0.085*	230.4 ± 101.9	248.4 ± 109.4	*0.443*§
Knee extension force, non-fractured (N)	241.3 ± 113.7	295.1 ± 117.8	*0.070*	271.3 ± 110.1	280.6 ± 124.8	*0.749*

Continuous variables are presented as mean ± SD and categorical variables as n (%).

§ *p*-value for continuous variables from Mann-Whitney U test (otherwise continuous variables analyzed with T-test and discrete variables with the Pearson χ^2 test)

TABLE 7 Characteristics of participants in ProMo study (IV) stratified by walking trajectory groups in walking outdoors and walking 500 meters. Walking trajectories were assessed with the linear latent trajectory modeling.

	Walking outdoors			**Walking 500 meters**		
	No-to-minor difficulty n = 50	**Catastrophic n = 31**	***p***	**No-to-minor difficulty n = 27**	**Catastrophic n = 54**	***p***
Age (years)	78.6 ± 7.2	82.2 ± 6.5	*0.362*	77.9 ± 6.4	81.0 ± 7.3	*0.035*
Women	42 (84)	21 (68)	*0.087*	23 (85)	40 (74)	*0.257*
Body height (cm)	161 ± 8	160 ± 10	*0.489*	161 ± 8	160 ± 9	*1*
Body weight (kg)	65.9 ± 11.6	65.6 ± 11.5	*1*	64.9 ± 10.1	66.3 ± 12.3	*0.136*
Number of chronic diseases	3.0 ± 1.7	3.8 ± 1.7	*0.343*	3.1 ± 1.8	3.5 ± 1.7	*0.634*
Osteoarthritis	5 (10)	5 (16)	*0.415*	0 (0)	10 (19)	*0.017*
Walking aid, outdoors before fracture	16 (35)	23 (77)	*<0.001*	6 (24)	33 (65)	*<0.001*
Falling indoors, year before the fracture	8 (16)	12 (39)	*0.024*	3 (11)	17 (32)	*0.041*
Falling outdoors, year before the fracture	16 (33)	12 (39)	*0.580*	8 (39)	20 (38)	*0.472*
Fracture type, femoral neck, S72.0	31 (62)	21 (68)	*0.600*	20 (74)	32 (59)	*0.190*
Type of surgery			*0.338*			*0.454*
Internal fixation	24 (48)	14 (45)		11 (41)	27 (50)	
Hemiarthroplasty	18 (36)	15 (48)		11 (41)	22 (41)	
Total hip replacement	8 (16)	2 (6)		5 (18)	5 (9)	
Duration of inpatient period (days)	18 ± 12	29 ± 18	*0.006*	17 ± 13	26 ± 16	*<0.001*
Offending pain, at discharge	12 (28)	17 (61)	*0.006*	7 (28)	22 (48)	*0.105*
Pain, 6wks after discharge (VAS, 0-600)	69.9 ± 77.9	169.8 ± 148.2	*0.002*	54.9 ± 74.4	134.1 ± 129.0	*0.004*
Prescribed pain medication (%)	27 (54)	23 (74)	*0.069*	15 (56)	35 (65)	*0.419*
Functional balance (BBS, 0-56)	45.3 ± 6.2	36.9 ± 11.5	*0.002*	46.8 ± 4.7	39.8 ± 10.4	*0.004*
Knee extension force, fractured (N)	187.5 ± 73.2	157.2 ± 67.9	*0.059*	191.0 ± 66.7	167.9 ± 74.6	*0.087*
Knee extension force, non-fractured (N)	249.6 ± 91.2	208.2 ± 77.8	*0.029*	252.9 ± 85.4	224.3 ± 89.0	*0.056*

Continuous variables are presented as mean ± SD and categorical variables as n (%).
p-value for continuous variables analyzed with median test and for discrete variables with the Pearson χ^2 test.

TABLE 8 Baseline characteristics of participants in ProMo study (III, V) stratified by randomized Intervention and Control groups.

	Intervention n = 40	Control n = 41	*p*
Age (years)	80.9 ± 7.7	79.1 ± 6.4	*0.249*
Women	31 (78)	32 (78)	*0.953*
Body height (cm)	161 ± 9	160 ± 9	*0.785*
Body weight (kg)	65.8 ± 11.9	65.9 ± 9.1	*0.968*
Number of chronic diseases	3 ± 2	3 ± 2	*0.581*
Fracture type, femoral neck, S72.0	27 (68)	25 (61)	*0.645*
Type of surgery			*0.719*
Internal fixation	19 (48)	19 (46)	
Hemiarthroplasty	15 (38)	18 (44)	
Total hip replacement	6 (15)	4 (10)	
Time since surgery (weeks)	9.3 ± 2.3	9.2 ± 3.6	*0.889*
Walking aid, indoors	28 (70)	24 (59)	*0.356*
Walking aid, outdoors	30 (75)	35 (85)	*0.276*
Lower body pain (VAS, 0-600)	120.4 ± 124.7	92.4 ± 112.7	*0.292*
Leg extension power deficit (W)	16.5 ± 25.9	22.6 ± 25.2	*0.967*§
Lower extremity performance (SPPB, 0-12)	5.8 ± 2.5	6.6 ± 2.2	*0.115*
Functional balance (BBS, 0-56)	40.5 ± 10.4	43.6 ± 8.5	*0.972*§
Stair climbing			*0.380*
No difficulties	20 (50)	24 (59)	
Some difficulties	10 (25)	12 (29)	
Great deal of difficulties	3 (8)	3 (7)	
Manage only with the help	4 (10)	2 (5)	
Unable to manage even with help	3 (8)	0 (0)	

§ *p*-value for continuous variables from median test (otherwise continuous variables analyzed with T-test and discrete variables with the Pearson χ^2 test).

5.2 Associations of type of surgical treatment, musculoskeletal pain, mobility limitation and physical inactivity after a hip fracture (I, II, IV)

5.2.1 Type of surgical treatment and musculoskeletal pain (I)

Participants with a previous hip fracture experienced statistically significantly more pain in hip and knee regions compared to the reference group (p=0.001). The internal fixation group experienced significantly greater musculoskeletal pain compared to the other study groups (Figure 6). In addition, pain was significantly greater in the hemiarthroplasty group than in the reference group. When measured almost two years after the hip fracture, the fractured hip was more painful among all the hip fracture groups, especially after internal fixation, compared to the average pain in the hip region among the reference group (Figure 7). However, no significant difference in pain was observed in the non-fractured side between the hip fracture groups and the reference group. Compared to the other hip fracture groups, internal fixation group had more pain in the knee on the fractured side (Figure 7). After adjustment for time since the most recent surgery, the statistical significance in pain in the knee on the fractured side increased further (internal fixation-hemiarthroplasty p=0.001, internal fixation-total hip arthroplasty p<0.001).

5.2.2 Type of surgical treatment and mobility limitation (I)

The participants with hemiarthroplasty used walking aids outdoors more often than those in the internal fixation or total hip replacement groups, while the participants in the reference group used walking aids outdoors significantly less than any of the hip fracture groups (Table 6). In addition, use of walking aids indoors was more prevalent among the participants with hip fracture compared to the reference group, but no differences between hip fracture groups were found. Maximal walking speed over ten meters was significantly greater, time at the Timed Up-and-Go test significantly shorter and functional balance better in the reference group than in the hip fracture groups. The internal fixation group was significantly faster in the 10-meter walk test than the hemiarthroplasty group and in the Timed Up-and-Go test than either hemiarthroplasty or total hip replacement groups. In the Berg Balance Scale, hemiarthroplasty group scored significantly lower than the internal fixation or total hip replacement groups. Although, these laboratory-based measurements suggested that hemiarthroplasty group was older and showed worse mobility ability than the other hip fracture groups, significantly more walking difficulties were perceived in the internal fixation than hemiarthroplasty or total hip replacement groups.

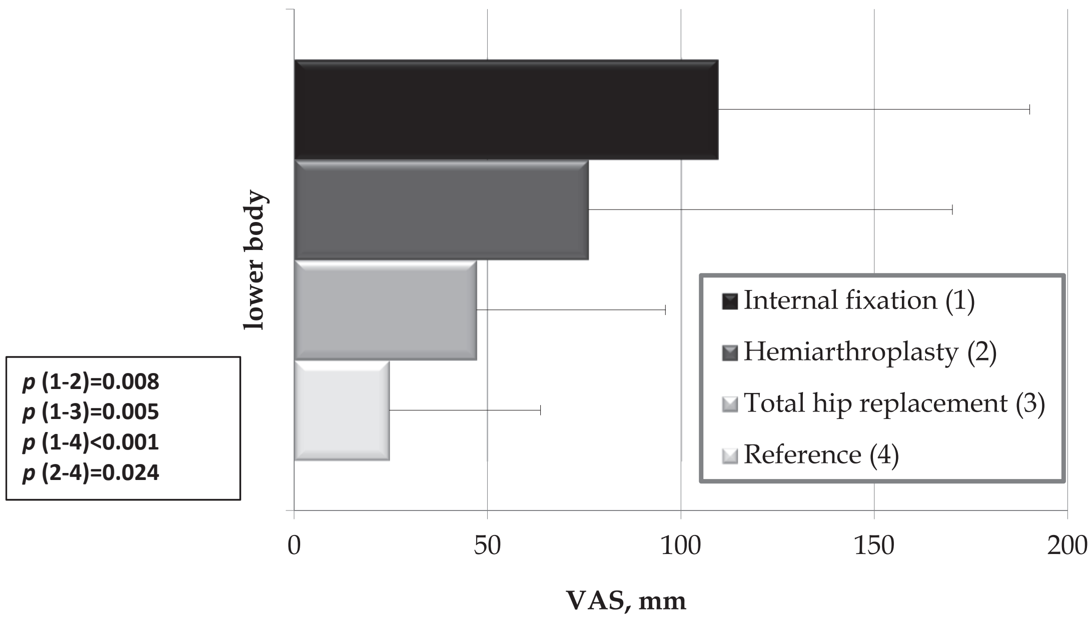

FIGURE 6 Musculoskeletal pain sum (mean and SD) in the hip and knee region on both sides of the body in the internal fixation (IF), hemiarthroplasty (HA), total hip replacement (THR) and reference (REF) groups and *p*-values for statistically significant differences between the study groups.

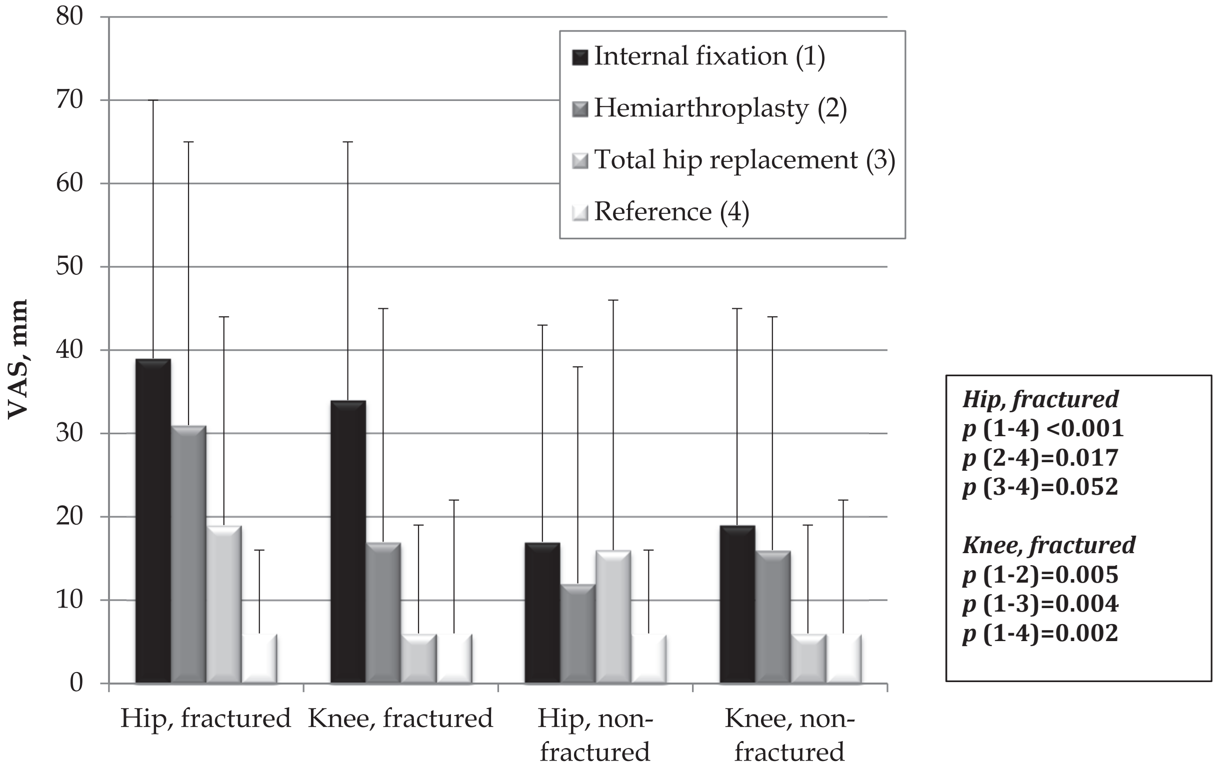

FIGURE 7 Musculoskeletal pain (mean and SD) in the lower extremity sites in the internal fixation, hemiarthroplasty, total hip replacement and reference groups and *p*-values for statistically significant differences between the study groups.

5.2.1 Musculoskeletal pain and physical inactivity (II)

Severe musculoskeletal pain was significantly more common among the physically inactive than physically active participants (62% vs. 31%, $p=0.011$). Balance confidence was worse in the physically inactive group than in the physically active group and among the participants with severe pain than less or no pain. Furthermore, the participants reporting severe pain used prescribed pain medication statistically significantly more often and had significantly higher body mass index compared to those in the less or no pain group.

At three years after hip fracture, 42% of the participants suffered severe musculoskeletal pain in the lower back, hip or knee region. Seventy per cent of this group also reported severe pain in the operated hip. A significant association was found between musculoskeletal lower body pain and physical inactivity. The participants with severe pain had three and a half times (OR 3.5, CI 95% 1.30–9.39) the risk for physical inactivity compared to those with less or no pain. Multivariate adjustments for balance confidence, time since fracture, number of chronic diseases and type of surgery did not materially change the estimate (OR 3.0, CI 95% 1.00–9.30).

5.3 Walking recovery and its determinants after hip fracture (IV)

5.3.1 Walking recovery trajectories after hip fracture

To analyze recovery in walking outdoors and walking 500 meters during the first months after hip fracture, assessments were performed at the hospital for pre-fracture status, at discharge to home and at an average of 6 weeks after discharge. The parametric bootstrapped likelihood ratio test showed that two groups, called Catastrophic and No-to-minor-difficulty, were more likely than one group to account for the trajectories in walking outdoors ($p<0.001$) and walking 500 meters ($p<0.001$). In both groups, however, walking difficulties increased, and among the majority of the participants recovery to the pre-fracture state was not observed (Figure 8).

In walking outdoors, the No-to-minor-difficulty trajectory (n=50) comprised participants with no pre-fracture mobility difficulties. At discharge, 42%, and at six weeks thereafter 26%, of this group reported no difficulties in walking outdoors. Twenty-two per cent of the participants in the Catastrophic trajectory (n=31) had reported pre-fracture no difficulties. Mobility difficulties increased at discharge and had increased at six weeks thereafter. Nearly half of the participants in the Catastrophic trajectory needed the help of another person in walking outdoors at discharge (44%) and at 6 weeks after discharge (46%).

In walking 500 meters, none of the participants in the No-to-minor-difficulty trajectory had pre-fracture walking difficulties. At discharge, 57% and at six weeks thereafter 63% of the participants reported some difficulties. In the Catastrophic trajectory, 19% were unable to walk 500 meters without the help of another person pre-fracture. Perceived difficulties increased dramatically after the fracture, as at discharge 58% and at 6 weeks after discharge 48% needed the help of another person.

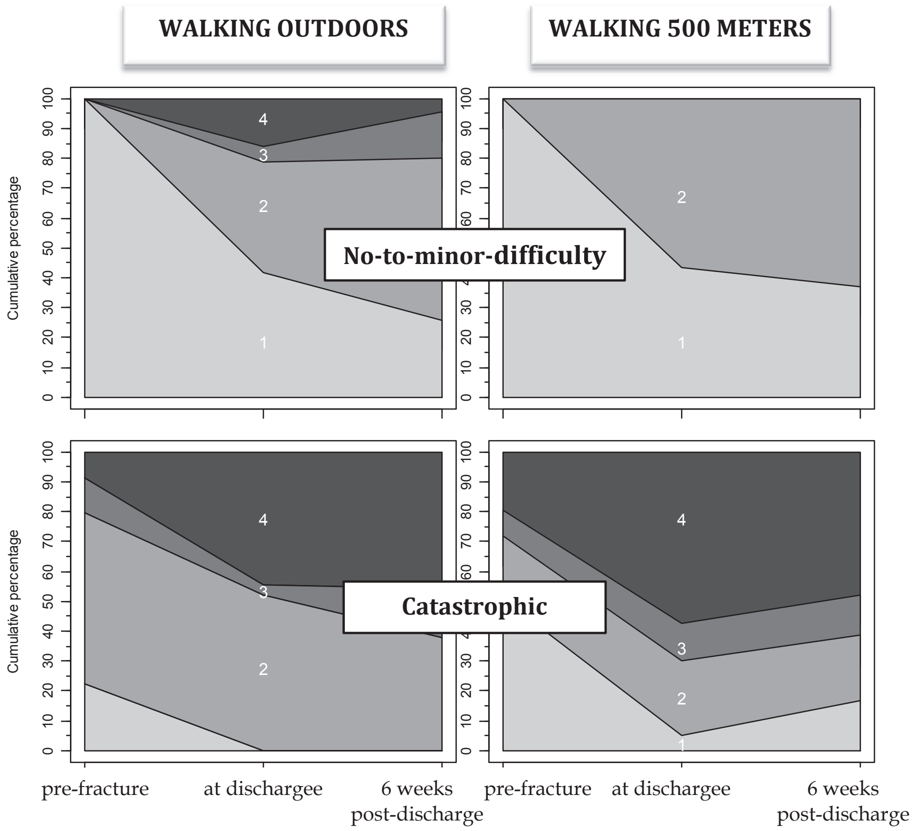

FIGURE 1 Trajectories for walking difficulties. Figures show the cumulative percentage of individuals within a response category at the three time points. Upper No-to-minor-difficulty trajectories and lower Catastrophic trajectories. (1=able to manage without difficulty, 2=able to manage with some difficulty, 3=able to manage with great deal of difficulty, 4=able to manage only with the help of another person or unable to manage even with help).

5.3.2 Determinants of walking recovery trajectories

Various determinants were associated with the recovery trajectories in walking outdoors and in walking 500 meters (Table 7). The pre-fracture use of walking aids and indoor falls during the previous year, were significantly more common among the Catastrophic trajectories than the No-to-minor-difficulty trajectories. Furthermore, a longer hospitalization period and offending pain at discharge were more prevalent among participants in the Catastrophic trajectory. In addition, at six weeks after discharge the participants in the Catastrophic trajectories experienced significantly more musculoskeletal pain in the lower extremities than those in the No-to-minor trajectory and also had lower functional balance and lower knee extensor force on the non-fractured side, reflecting their worse overall physical function in the Catastrophic trajectory weeks after returning to live in the community.

Logistic regression modeling adjusted for age and gender was performed for the determinants, which differed significantly between the walking trajectories (Table 9). In walking outdoors and walking 500 meters, participants using walking aids pre-fracture had six to eight times the risk and those who fell indoors prior to the fracture four times the risk for ending up in the Catastrophic trajectory, compared to those who had no walking aids or who had not fallen indoors pre-fracture. In addition, every day spent in hospital increased the risk for ending up in the Catastrophic trajectory by four to five per cent. In walking outdoors, those suffering from offending pain at discharge had nearly six times the risk for membership of the Catastrophic trajectory. In addition, a mean increase in musculoskeletal pain six weeks after discharge by ten points (VAS, range 0-600) increased the risk for ending up to the Catastrophic trajectory by 9% in walking outdoors and walking 500 meters. One-point decrease in the functional balance scale increased the risk for membership of the Catastrophic trajectory by 7-14% in main outcome variables. In addition, in walking outdoors a decrease of ten newton in knee extension force on the non-fractured side increased the risk for ending up to the Catastrophic trajectory by 7-8%. After adjusting the model for all the significantly associated determinants, only minor changes in the associations were observed.

TABLE 9 Binary logistic regression model for statistically significant variables as predictors for catastrophic trajectory (IV).

	Walking outdoors		Walking 500 meters	
	Model I OR (95% CI)	**Model II OR (95% CI)**	**Model I OR (95% CI)**	**Model II OR (95% CI)**
Walking aid, outdoors before fracture	6.55 (2.05-20.96)	7.91 (2.20-28.51)	5.77 (1.83-18.20)	5.49 (1.70-17.77)
Falling indoors, year before the fracture	4.19 (1.32-13.32)	3.74 (1.04-13.51)	4.49 (1.11-18.10)	4.64 (1.01-21.36)
Duration of inpatient period (days)	1.05 (1.01-1.09)	1.04 (1.00-1.09)	1.05 (1.00-1.10)	1.05 (1.00-1.10)
Offending pain, at discharge	5.97 (1.89-18.89)	5.66 (1.70-18.82)	-	-
Pain, 6wks after discharge (VAS, 0-600)	1.09 (1.04-1.15)	1.10 (1.03-1.17)	1.09 (1.02-1.16)	1.07 (1.00-1.15)
Functional balance (BBS, 0-56)	0.89 (0.82-0.96)	0.93 (0.85-1.02)	0.86 (0.77-0.96)	0.90 (0.81-1.01)
Knee extension force, non-fractured (N)	0.92 (0.85-0.98)	0.93 (0.84-1.02)	-	-

Model I: Odds ratio and 95% confidence interval for statistically significant variables between trajectories adjusted for age and gender.
Model II: Odds ratio and 95% confidence interval for all statistically significant variables from Model I, adjusted for age and gender.
VAS and knee extension force were divided by 10 for the regression analysis

5.4 Effects of the ProMo individually tailored multi-component home-based rehabilitation program on mobility disability (V)

Based on the generalized estimating equation (GEE) models, the ProMo rehabilitation program had no statistically significant effects on the short-term outcomes of functional balance (BBS) or physical performance (SPPB) (Figure 9). However, with respect to the long-term main outcome, negotiating stairs, the intervention group perceived significantly less difficulties than controls after the intervention (p=0.001, Figure 10). The participants in the ProMo rehabilitation reported lower values for perceived difficulties after 12 months of rehabilitation compared with the pre-fracture level.

The effects of the ProMo rehabilitation were also analyzed in the context of the disablement process, using a path model adjusted for age and number of chronic diseases (Figure 11). The association between functional balance measured by the Berg Balance Scale at three months into the rehabilitation and leg extension power deficit at baseline differed between the study groups. The coefficient for the intervention group was not significant, whereas the effect was unexpectedly positive in the control group, indicating that the large baseline deficit was related to better functional balance values. Less difficulty in negotiating stairs at six and twelve months correlated significantly with better functional balance at three and six months in the intervention group (p<0.001), but not in the control group (group difference between functional balance at three months to negotiating stairs at six months p=0.011, and from six to twelve months p<0.001). When SPPB was incorporated into the model instead of BBS, the associations between negotiating stairs at twelve months and functional limitation at six months were significantly different between the study groups (p<0.001). Less difficulty in negotiating stairs correlated with a better SPPB score among the intervention group (p<0.001) but not among the controls (p=0.550).

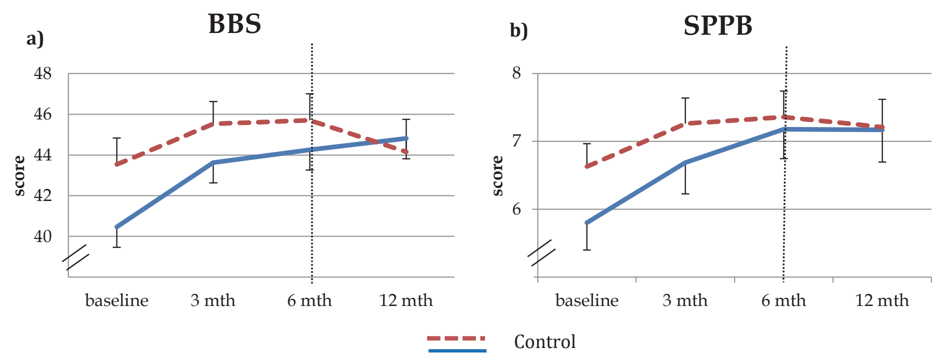

FIGURE 9 Short-term outcome of ProMo. Changes in the functional balance and in the functional limitation for the intervention and control groups; *p*-value for the group by the time interaction term is shown from baseline to six months; a) Berg Balance Scale (BBS), group by the time interaction from baseline to 6 months $p=0.188$. b) Short Physical Performance Battery (SPPB), group by the time interaction from baseline to 6 months $p=0.440$. In addition, group by the time interactions from baseline to 12 months were $p=0.185$ for BBS and $p=0.414$ for SPPB.

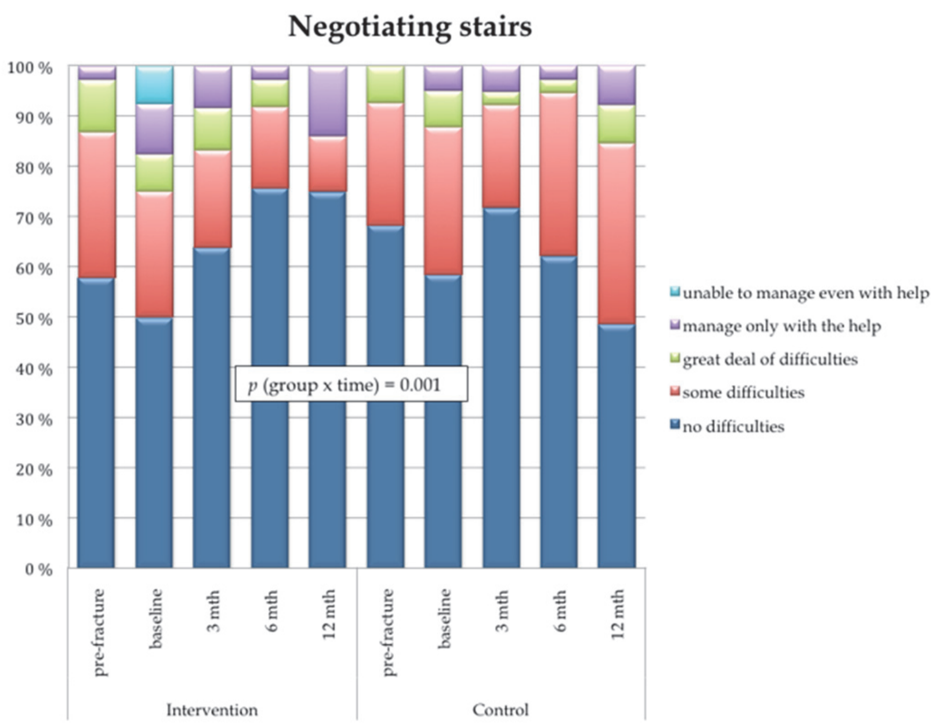

FIGURE 10 Changes in perceived difficulties in negotiating stairs for the intervention and control groups at pre-fracture, baseline, three, six, and twelve months; *p*-value for the group by time interaction term. The group by the time interaction from pre-fracture to 12 months $p=0.001$.

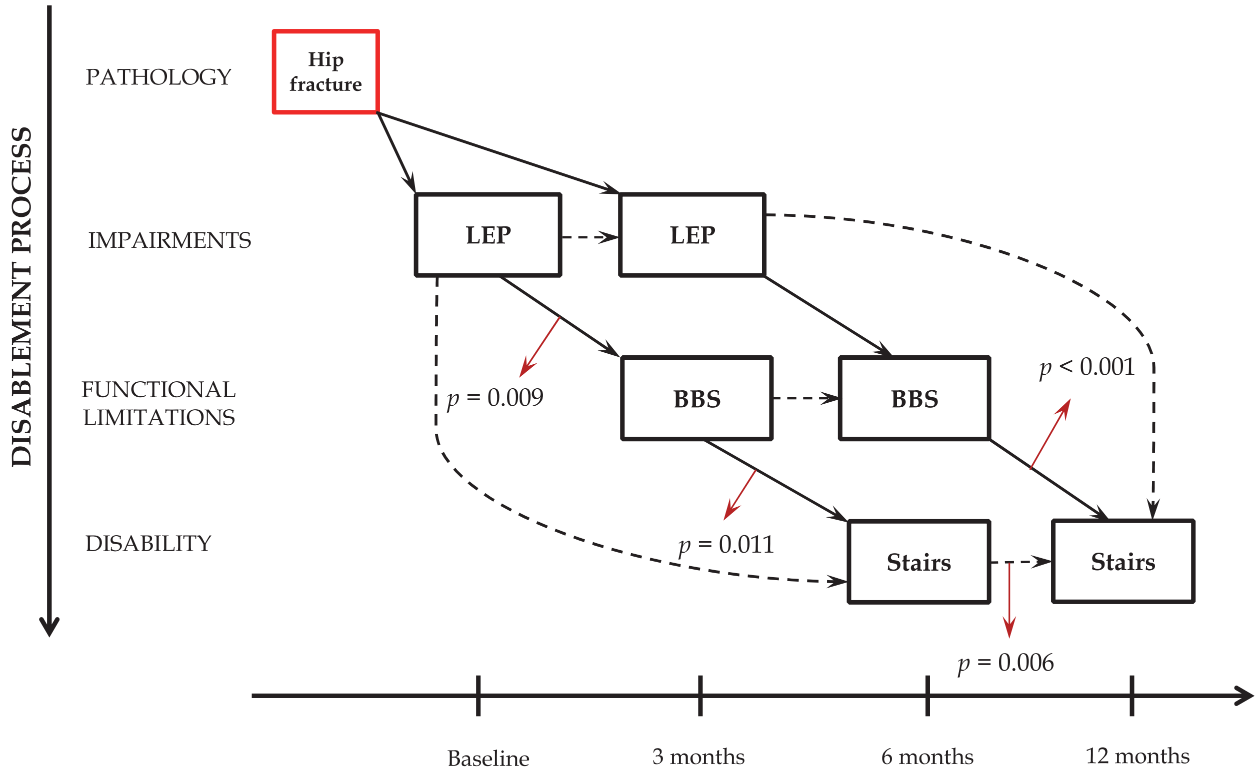

FIGURE 11 Schematic drawing of the study presents timetable of the measurements related to the pathway of the disablement process. *p*-values are the statistical differences of path coefficients from the mixture path models between the study groups. Model is adjusted for age and number of chronic diseases.

6 DISCUSSION

This study was conducted to examine the mobility recovery process after hip fracture and to examine the effects of a yearlong multi-component home-based rehabilitation program on mobility recovery among community-dwelling older people after hip fracture.

This study showed that major difficulties in walking outdoors continued to be common on average ten weeks after a hip fracture. The use of walking aids and falls before the fracture, a longer inpatient period and the presence of musculoskeletal pain predicted catastrophic decline in walking ability after the hip fracture. The results also suggested that on average two to three years post hip fracture, the type of surgical treatment was associated with musculoskeletal pain and mobility limitations and that severe musculoskeletal pain was a risk factor for physical inactivity.

The multi-component home-based rehabilitation program improved mobility recovery assessed as perceived difficulties in negotiating stairs over standard care. After the yearlong rehabilitation period the mobility of the intervention group was better than the pre-fracture level, whereas in the usual care control group mobility was worse than before the fracture. During the rehabilitation intervention, mobility recovery followed the logic of the re-ablement pathway, but this was not the case for those receiving standard care. In the intervention group, fewer difficulties in negotiating stairs at six and twelve months correlated with better balance three months before.

6.1 Mobility recovery after hip fracture

Early mobility recovery. Participants with a recent hip fracture experienced severe difficulties walking outdoors six weeks after discharge to home from the inpatient period (IV). Two trajectories for the recovery of walking outdoors and 500 meters were found: No-to-minor-difficulty and Catastrophic. The No-to-minor-difficulty trajectory comprised participants with no pre-fracture walking difficulties and only minor difficulties post fracture. Most of the participants in the Catastrophic trajectory had pre-fracture walking difficulties followed by a steep decline post fracture. On average, six weeks after discharge, nearly half of the participants in the Catastrophic trajectory needed the help of another person when walking outdoors. Our results are in line with those of previous studies, showing that hip fracture patient often have mobility difficulties after discharge (Alley et al. 2011, Magaziner et al. 2000, Ganz et al. 2007, Shyu et al. 2004, Taylor, Barelli & Harding 2010). For example, Alley et al (2011) reported that 67% of their participants had difficulties in walking one block and 73% in negotiating stairs two months after a hip fracture (Alley et al. 2011). These results suggest that current rehabilitation practice after hip fracture does not sufficiently take into account the prerequisites for safe walking and the ability to return to community activities.

Determinants for early mobility recovery. Determinants predicting the risk for ending up in the Catastrophic walking trajectories were found at all measurement time points: pre-fracture, inpatient period and six weeks after discharge (IV). Use of a walking aid and indoor falls before the fracture, as well as age and osteoarthritis predicted deterioration in walking ability after the fracture. In addition, length of the inpatient period, offending pain in the fractured limb at discharge, poor functional balance, decreased lower extremity muscle strength, and prolonged lower body pain six weeks after discharge were associated with catastrophic decline in outdoor walking ability. Previous studies have similarly shown, that pre-fracture use of a walking aid (Sylliaas et al. 2012b, Ganz et al. 2007), high age (Kristensen et al. 2010, Holt et al. 2008b) and a longer inpatient period (Shyu et al. 2004) predict poor mobility recovery after a hip fracture. A longer inpatient period may reflect poor health status or complications during the acute treatment of the fracture. Our results are also in line with a previous study, which found that the change in functional status before an injurious fall was associated with functional recovery trajectories after the fall (Gill et al. 2013b). Previous studies have also shown that persistent muscle weakness, balance impairment, walking limitations and disability often co-occur after a hip fracture (Portegijs et al. 2008, Sihvonen et al. 2009). One important finding from our study was that musculoskeletal pain at discharge and at six weeks thereafter predicted walking recovery trajectories. For example, participants with offending pain at discharge had a nearly six fold greater risk for catastrophic decline in outdoor walking ability than those without pain. Acute pain resulting from a hip fracture and related surgery can restrict the mobility recovery leading to overall activity restriction. According to previous studies, other suggested predictors of poor recovery after a hip fracture are clinical condition, gender and type of surgical treatment (Ganz et al. 2007, Penrod et al. 2008, Kristensen et al. 2010, Maggi et al. 2010, Yonezawa et al. 2009, Aronow et al. 2012, Shyu et al. 2004, Holt et al. 2008a, Holt et al. 2008b).

Long-term mobility recovery. Two years after a hip fracture, participants of this study had significantly lower overall mobility, used walking aids more often, had slower walking speed in the 10-meter walk and Timed Up-and-Go tests, had worse functional balance, and had a lower physical activity level than the control group (I). These results are in line with those of previous studies showing that mobility difficulties after a hip fracture are persistent and can last for years (Magaziner et al. 2000, Shumway-Cook et al. 2005, Vochteloo et al. 2013). A large proportion of older community-dwelling hip fracture patients are still homebound and one-fifth immobile one year after the event (Vochteloo et al. 2013).

Determinants of long-term mobility recovery. Participants with hip fracture on average two years earlier reported significantly more musculoskeletal pain in the lower body than age-matched controls without earlier lower limb traumas (I). At an average of three years after hip fracture, 42% of the participants suffered from severe musculoskeletal pain in the lower body. Of this group, more than two-thirds reported severe pain in the operated hip (II). In addition, participants operated with internal fixation had more pain than those operated with hemiarthroplasty or total hip replacement, and pain was present not only in the operated hip but also more widely in the lower body, especially on the side of the operated leg (I). Our results support with earlier findings showing that after hip fracture older people suffer from long-term pain (Herrick et al. 2004) and that internal fixation induces more pain than arthroplasty (Dasch et al. 2008, Foss et al. 2009, Gjertsen et al. 2010, Lu-Yao et al. 1994), or, in particular, total hip replacement (Blomfeldt et al. 2005). In addition, our results showed that participants with internal fixation reported significantly more pain in the knee on the operated side than the hemiarthroplasty or total hip replacement groups (I). According to previous studies, osteoarthritis is the most common cause of knee pain among older people (Mäntyselkä et al. 2001, Thomas et al. 2004). However, we found no difference in osteoarthritis between the study groups. Nevertheless, pain in the knee is associated with mobility limitations, even if there are no detectable signs of osteoarthritis (Hochberg et al. 1989, Creamer, Lethbridge-Cejku & Hochberg 2000).

Our results (II) showed a correlation between musculoskeletal pain and physical inactivity even after controlling for potential confounding factors, such as balance confidence, time since fracture, number of chronic diseases and type of surgical treatment. This result is in line with earlier studies showing that musculoskeletal pain is among the major reasons for low physical activity in older populations (Ashe et al. 2009, Stubbs et al. 2013). In the present study, the participants with internal fixation reported more pain and perceived more walking difficulties than patients with hemiarthroplasty or total hip replacement (I). Those results are in line with a recently published randomized controlled trial, which showed that physical functioning, activities of daily living and quality of life were better two years after hemiarthroplasty than internal fixation (Stoen et al. 2014). Regardless of the higher prevalence of pain, the participants with internal fixation showed better results in performance-based mobility and balance tests than those with hemiarthroplasty. The present results supported by those of other studies showing that pain in older people is directly associated with perceived mobility difficulties and less with performance-based measurements of mobility and balance (Eggermont, Shmerling & Leveille 2010, Leveille et al. 2001, Leveille et al. 2007, Weiner et al. 2003). Some of the differences in the present performance-based tests might also be explained by the older age of the patients with hemiarthroplasty and by the higher proportion of men in the internal fixation group. However, the time since hip surgery was longest among those with internal fixation, and yet they continued to experience more musculoskeletal pain and reported more walking difficulties than the other study groups. In addition, although statistically significant differences in perceived walking difficulties were observed between surgical treatments on average three years after a hip fracture (I), no differences between the different types of surgical treatment were detected when studying walking recovery soon after discharge from hospital (IV). It is possible that the manifestation of walking difficulties associated with the type of surgical treatment develops over a longer period of time.

Our findings are in line with those of earlier studies showing that with the standard rehabilitation practice the vast majority of older hip fracture patients do not recover their pre-fracture level of mobility and functional capacity (Young, Fried & Kuo 2010, Visser et al. 2000, Sihvonen et al. 2009). Hip fracture patients often also suffer from comorbidities, have a sedentary lifestyle and functional impairments, all of which underlie the complexity of their situation. The exact mechanisms underlying between musculoskeletal pain, type of surgical treatment, physical inactivity and mobility limitation are not known. The causes of pain after hip fracture might include restrictions in the range of motion of the hip joint, shortening of limb length and weight-bearing limitations in the affected leg, which have been reported to be more common after internal fixation than after arthroplasty (Parker et al. 2002). These factors could further lead to muscle strength deficit and modifications in stance, standing posture and walking. Such changes might lead to pain and induce increased loading on the low back and on joints in the lower body, which in turn lead to activity restrictions, and eventually to a circular decline with further muscle strength decline and consequent mobility disability. However, it is also possible that muscle weakness contributes to musculoskeletal pain and fear of pain, which then leads to avoidance of physical activity, placing people on the pathway to mobility decline and further physical inactivity (Fransen & McConnell 2008, Vlaeyen & Linton 2000). In all, mobility difficulties after hip fracture complicate involvement in community activities, make daily life more difficult and increase the risk for institutionalization. Our results together with those of earlier studies underline the need for the improving pain management and rehabilitation practices after hip fracture.

6.2 Effects of the ProMo rehabilitation program on mobility recovery after hip fracture

The novel finding of this study was that the ProMo rehabilitation program improved mobility recovery over standard care during the year following a hip fracture. Compared to the pre-fracture level of mobility, the ProMo rehabilitation reduced and the control treatment increased perceived difficulties in negotiating stairs one year after discharge relative to the pre-fracture situation. The intervention group reported less difficulty in negotiating stairs after the rehabilitation than pre-fracture, (at least minor difficulties 42% vs. 25%, respectively). In addition, our statistical analysis was unique in the context of the intervention study, and we showed that in the intervention group the correlations between the different tiers of function followed the expected time line and the reverse logic of the disablement process model, called re-ablement. According to the pathway, fewer difficulties in negotiating stairs at six and twelve months correlated with better balance at three and six months in the intervention group. The same association was not seen among the controls. The fact that the intervention decreased perceived difficulties in negotiating stairs below the pre-fracture level supports the idea of re-ablement.

Only some long-term home-based rehabilitation interventions targeting mobility recovery after hip fracture have been published (Crotty et al. 2002, Latham et al. 2014, Orwig et al. 2011, Shyu et al. 2010, Tinetti et al. 1999, Tsauo et al. 2005, Ziden, Frandin & Kreuter 2008). We found seven trials in which the effects of an intervention on mobility were assessed. Among these mobility was the main outcome in five trials (Crotty et al. 2002, Latham et al. 2014, Shyu et al. 2010, Tsauo et al. 2005, Ziden, Frandin & Kreuter 2008). However, the whole mobility re-ablement process after a hip fracture was not studied in any of these trials as we did in the ProMo study. Three studies were published before the ProMo study was launched (Crotty et al. 2002, Tinetti et al. 1999, Tsauo et al. 2005). Among these seven trials modest but significant improvements in mobility were reported (Crotty et al. 2003, Latham et al. 2014, Orwig et al. 2011, Shyu et al. 2010). A four-month intervention had no effect on Timed Up-and-Go test (TUG) (Crotty et al. 2002). However, in the same study, TUG performance improved at the eight-month follow-up in the intervention but not in the control group (Crotty et al. 2003). Shyu et al. (2010) reported better walking ability after an intervention, which continued till three months after discharge. In addition, a recently published study investigated the effects of a six-month functionally oriented exercise intervention on physical performance and mobility among older community-dwelling people who had sustained a hip fracture (Latham et al. 2014). In line with our results, this study found that the intervention reduced perceived difficulties in basic mobility tasks, including e.g. climbing stairs. However, they also observed a significant improvement in the short physical performance battery (SPPB), which was not detected in our study. The participants in the study by Latham et al. were not fully comparable with ours. At the baseline, the average time since the fracture was over nine months, compared to nine weeks in our study. Nine months after discharge, the acute recovery phase was behind, and the rehabilitation provided as part of standard care had ended. Consequently, the intervention effect might stem in part from the more passive control group in terms of rehabilitation in addition to natural recovery having slowed down. Natural recovery is highest during the first three months (Magaziner et al. 2000). In our study, mobility improved in all participants regardless of their study group during the first months due to natural healing. Consequently, the improvement in SPPB at six months did not differ between the groups in our study, in contrast to Latham et al. (2014) who recruited participants after the natural healing process was over.

The ProMo rehabilitation program was designed on the basis of the existing knowledge of the determinants underlying mobility recovery gathered from our own and other previously published studies. In addition, ProMo was inspired by the encouraging results of a previous rehabilitation study conducted among frail community-dwelling older people (Gill et al. 2002). The aim of the ProMo rehabilitation was first to lay the foundation for an adequate mobility and physical exercise program, through with light modification of home environmental hazards, walking aid adjustments, guidance for safe walking and pain management. After that, the intervention continued with a progressive home exercise program to increase muscle strength and decrease muscle power deficit (impairment), improve postural balance (functional limitation) and increase physical activity and other tasks related to coping with more demanding tasks in one's own environment (disability). The content and timing of the intervention acknowledged the fact that more complex and physically demanding functions need longer recovery time than more automated functions. The prerequisites for walking are sufficient muscle strength (Portegijs et al. 2008, Portegijs et al. 2009) and postural balance (Portegijs et al. 2012, Sihvonen et al. 2009). With good postural balance, walking requires less muscle strength (Rantanen et al. 1999). The study protocol utilized a theory-based approach to both the mobility assessments and the intervention, but the approach and long follow-up is novel in common rehabilitation practice. Therefore this study investigated a topic, with high societal and human relevance.

It is important to support the functional independence of older community-dwelling people. Restoring mobility after a hip fracture makes it possible for the individual to continue participating in and contributing to the community. The results of this study showed that mobility disability among community-dwelling hip fracture patients can be reversed by a multi-component home-based rehabilitation that is progressive and long enough to build up the capabilities needed in everyday life.

6.3 Methodological considerations

This thesis is based on two different trials, which recruited hip fracture patients through the hospital register. From the previously conducted Hip-Asymmetry study, baseline data only were used. From the ProMo study, whole data from hospital admission to the end of the intervention were studied. This thesis reports the analysis of the main outcome of the ProMo study.

Recruitment. In clinical populations, the recruitment of participants is challenging, especially in studies requiring frequent travelling or where long-term interventions are incorporated into the study design. In both studies (Hip-Asymmetry and ProMo), the sample size calculated according to the RCT design. Recruitment of the participants in both data sets was intensive. In the Hip-Asymmetry study, of the 451 potential participants we informed about the study, every sixth eventually participated. In the ProMo study, the personnel of the central hospital and local health care centers identified all potential participants who met the inclusion criteria and informed them about the study. During the inpatient period, the researchers interviewed all the hip fracture patients who were interested in the study. Collaboration with the hospital and the health care centers was good. In the ProMo study, one in four of the identified hip fracture patients participated in the study The success the recruitment to both studies is comparable or higher than in the earlier published RCTs among clinical populations (Chang et al. 2004, Frobell, Lohmander & Roos 2007). However, the target number of participants had not been quite reached at the point where owing to the scheduling of the study, it became unfeasible to continue the recruitment process any longer. Both studies were slightly underpowered, compared to the expected number of participants needed for a statistically significant intervention effect. Larger sample sizes might have yielded even clearer results.

In study IV, the rather small sample size in the secondary analysis of ProMo, might have hindered detection of all the predictors of walking recovery. With a larger sample size more than two recovery trajectories might have been found. However, we believe that we have identified the most important paths characterizing early walking limitation after hip fracture and the key determinants defining outdoor walking recovery.

Participants. The participants were community-dwelling older hip fracture patients without severe cognitive dysfunctions who were willing to participate in a randomized controlled study with an exercise rehabilitation intervention. Our participants had markedly poorer mobility and balance, were more physically inactive, and had more pain than the age-matched controls who had no previous major fractures or injuries in the lower limbs. Our sample, however, is not representative of all hip fracture patients, for example nursing home residents, or persons who were too frail to participate in physical testing. It is likely that our participants had better cognition and overall physical capacity than hip fracture patients in general.

Assessments. Measurements were performed blinded to the study groups. Assessments were conducted in the same laboratory, with the same equipment in both studies. The laboratory assessment schedule was designed to ensure that measurements were conducted in the same order and the same time of the day for each participant at all follow-up points. The laboratory assessments in both studies started with a comprehensive medical examination performed by a physician and nurse. To ascertain safe participation in the measurements and intervention, contraindications to the tests were evaluated according to the guidelines of the American College of Sports Medicine (2010). The measurements were carefully selected based on validity, reliability, psychometric properties and feasibility. The assessments represented the different tiers of the disablement process. Currently, no standard methods exist for assessing the mobility of hip fracture patients and consequently the results of the existing studies are not wholly comparable.

Feasibility of the intervention. The ProMo rehabilitation proved to be feasible in the home setting. Dropout from ProMo was very low (one in the intervention and two in the control group). The intervention was well tolerated considering that the participants were people who had recently experienced a traumatic event and who also had many vulnerabilities. Adverse events or the use of health care services did not differ between the intervention and control groups. In all cases, suspension for the intervention occurred for medical reasons and the causes were unrelated to the intervention. Compliance with the home exercises was high, and for the physical activity counseling excellent. The rehabilitation program was organized with a minimal number of home visits and without specific training equipment. Only one physiotherapist was needed to conduct the intervention.

Data quality. The quality of the data was good while the missing data rates were low.

Study designs. This research included both observational and RCT designs. The observational studies included cross-sectional, retrospective and prospective designs. Limitations typical of cross-sectional and retrospective studies include recall bias, selection bias and uncertainty about the temporal order of events, rendering conclusions about causality uncertain. Nowadays, most clinical decisions are expected to be made on the basis of scientifically valid knowledge. One of the most recognized study designs is the randomized controlled trial. Both data sets in this study were based on randomized controlled trial designs, although in the Hip-Asymmetry study only baseline data were used. Both studies were conducted according the principles of Consort Statement, which aims to improve the reporting and transparency of RCT studies. The previous hip fracture research is mostly based on efficacy-driven research, in which the effects of specified short-term interventions without longer follow-up have been studied among a homogenous group of hip fracture participants. These studies have been performed under optimal conditions with specifically designed and arranged training protocols and facilities. A rehabilitation program that shows significant effects in an efficacy study might not do so under real-world conditions (Flay et al. 2005). Therefore, the ProMo rehabilitation program was designed and implemented in real-world condition so as to increase effectiveness. All the RCT analyses were performed according to the intention-to-treat principle, which supports the aim of determine the true effectiveness of the intervention.

Ethical considerations. Studying older people raises various ethical considerations. For example older people often have many comorbidities and cognitive impairments; these can have effects on adherence and compliance with the intervention (Newman & Cauley 2012). The exclusion criteria were based solely on medical considerations and not, for example, on probability of dropout or poor adherence. We systematically collected information on adverse events as this knowledge in needed in assessing the outcome and for implementation of the study. Due to the vulnerability of the elderly participants the study protocol was designed such that the assessments would not be too exhausting for them. A physician was available during all measurements.

6.4 Implications and future directions

Currently, there is only weak evidence on the efficacy of outpatient rehabilitation for hip fracture patients. The ProMo rehabilitation was shown to be effective in the Finnish health care context. However, due to variation in the organization of inpatient and outpatient rehabilitation between countries, more studies on multi-component home-based rehabilitation after a hip fracture in different cross-cultural settings are needed. Moreover, the need for longer follow-ups after rehabilitation trials has also been acknowledged (Handoll, Sherrington & Mak 2011). If the final follow-up is at the endpoint of the intervention, its long-term benefits remain uncertain.

Recognition of comorbidities, impairments, and type of surgical treatment are necessary when planning individually tailored rehabilitation programs for recovery of mobility and functional capacity. The results of this study showed that more accurate information about pre-fracture functioning and inpatient complications should be gathered and incorporated into individualized rehabilitation programs to optimize the possibilities for mobility recovery. To promote the societal participation and independent living after a hip fracture, patients with a poor prognosis for mobility recovery need targeted and progressive rehabilitation and adequate pain management. This information would help not only in planning outpatient rehabilitation, but also in planning inpatient rehabilitation. Monitoring mobility recovery after discharge should also be part of standard care.

While, many recently published randomized controlled trials have investigated the effects of different surgical treatment of hip fractures, none have studied rehabilitation interventions among different surgical treatment groups. Studies investigating rehabilitation programs after different types of surgical treatment are required so as to find ways to effectively restore functioning for all patients irrespective of type of surgery.

Clear guidelines for outpatient rehabilitation after a hip fracture should be established. Implementation studies should then assess the critical pull and push factors for adopting these guidelines. The multi-component home-based rehabilitation presented in this study is low cost and easy to implement in clinical practice, as it can be organized with only a few home visits and phone calls, and it does not involve any specific training equipment. In addition, if the present type of mobility rehabilitation could help to lengthen the time spent living in one´s own home, in effect reducing premature institutionalization, then such rehabilitation becomes extremely cost-effective.

Recovery of mobility is highly important after a hip fracture. The results of this study show that the vicious circle of the disablement process leading to mobility disability and jeopardizing independence in the community, can be prevented with progressive rehabilitation, if it extents over a long enough period.

7 MAIN FINDINGS AND CONCLUSIONS

The main findings and conclusions can be summarized as follows:

1. Walking difficulties increase catastrophically after hip fracture surgery and related discharge from hospital. Two trajectories for outdoor walking recovery were found: No-to-minor-difficulties and Catastrophic. The underlying determinants predicting the most of the risk for ending up in the Catastrophic walking trajectory were use of walking aids and indoor falls before the fracture, length of the inpatient period, and prolonged musculoskeletal pain.

2. Musculoskeletal lower body pain is common years after a hip fracture. Severe musculoskeletal pain was associated with physical inactivity and also with type of surgical treatment, as the participants with internal fixation experienced significantly more pain. Internal fixation was further associated with perceived mobility difficulties.

3. The individually tailored multi-component home-based rehabilitation program improved mobility recovery over standard care during the year following a hip fracture. Compared to the pre-fracture level, the intervention group reported even less difficulties in negotiating stairs after rehabilitation. In addition, among the intervention group, mobility recovery followed the logic of the re-ablement pathway. Fewer difficulties in negotiating stairs at six and twelve months correlated with better balance three months earlier.

4. The underlying determinants for mobility limitation should be acknowledged in clinical practice when designing outpatient rehabilitation after a hip fracture. Pain management should be an essential part of health care among hip fracture patients. With a yearlong individually tailored multi-component home-based rehabilitation, mobility can be recovered to the pre-fracture level or even better. Outpatient rehabilitation after a hip fracture should be

persistent and progressive and guidelines for current practice should be improved.

5. Future studies among hip fracture patients should investigate the cost-effectiveness of rehabilitation and focus on the implementation of outpatient rehabilitation as part of standard care.

YHTEENVETO (FINNISH SUMMARY)

Kotona asuvien iäkkäiden lonkkamurtumapotilaiden liikkumiskykyä selittävät tekijät sekä liikkumiskyvyn kuntoutus murtuman jälkeen

Lonkkamurtuma on yksi ikääntyneiden vakavimmista tapaturmista ja se voi johtaa pysyviin fyysisiin rajoitteisiin. Lonkkamurtumapotilaat ovat keskimäärin 80-vuotiaita, mistä johtuu että heillä on usein myös muita sairauksia ja fyysisiä rajoitteita, jotka luovat haasteita kuntoutumiselle. Heikko kuntoutuminen vaikeuttaa potilaan itsenäistä kotona selviytymistä, mutta on myös kallis terveydenhuoltojärjestelmälle. Suomessa yhden lonkkamurtuman hoito maksaa keskimäärin 20 000 € ensimmäisen murtuman jälkeisen vuoden aikana. Noin kymmenen prosenttia lonkkamurtuman vuoksi leikatuista leikataan uudestaan, uusintaleikkaukset lisäävät entisestään kuluja ja hidastavat kuntoutumista. Suomessa tapahtuu vuosittain noin 7600 lonkkamurtumaa. Ennusteiden mukaan lonkkamurtumat lisääntyvät edelleen väestön ikääntyessä.

Liikkumiskyvyn palautuminen lonkkamurtuman jälkeen on haasteellista. Aiemman tutkimustiedon mukaan suurimmalla osalla murtuman kokeneista liikkumiskyky ei palaudu murtumaa edeltäneelle tasolle. Kohtuullista liikkumiskykyä tarvitaan päivittäisistä toiminnoista selviytymiseen ja itsenäisen asumisen mahdollistamiseen. Hyvän liikkumiskyvyn on todettu ehkäisevän uuden lonkkamurtuman syntymistä, laitoshoitoon joutumista sekä ennenaikaista kuolemaa. Korkea ikä, liikkumiskyvyn vaikeudet ennen murtumaa, murtumatyyppi, leikkaustapa sekä viivästynyt leikkaus, ovat yhteydessä liikkumiskyvyn vaikeuksiin. Riittävä lihasvoima on edellytys liikkumiskyvylle. Lonkkamurtuma johtaa alaraajojen lihasvoiman heikkenemiseen, etenkin murtuneen jalan puolella. Heikentynyt lihasvoima on yhteydessä tuki- ja liikuntaelimistön kipuun, heikkoon tasapainoon, kävelyn rajoittumiseen sekä liikkumiskyvyn heikkenemiseen. Tasapainovaikeudet ja kaatumisenpelko rajoittavat edelleen liikkumis- ja toimintakykyä. Näistä tekijöistä johtuen etenkin tehtävät, jotka vaativat sekä lihasvoimaa että tasapainoa, kuten porraskävely, palautuvat hitaasti lonkkamurtuman jälkeen. Tuki- ja liikuntaelimistön kipu lonkkamurtuman jälkeen heikentää tasapainoa ja rajoittaa liikkumiskykyä. Liikkumattomuus saattaa aiheuttaa lisää kipuja ja kiihdyttää toiminnan vajauksien syntyä.

Vaikka lonkkamurtumia ja kuntoutumista on jo aiemmin tutkittu melko paljon, ei vieläkään ole olemassa yleisesti hyväksyttyjä kuntoutusohjeita, joiden tavoitteena olisi liikkumiskyvyn palauttaminen. Etenkin tutkimustietoa pidempikestoisesta moniosaisesta kotikuntoutuksesta on vielä vähän, vaikka kotikuntoutuksen etuina on sen kustannustehokkuus ja saavutettavuus juuri sairaalasta kotiutetuilla potilailla. Aiempien kokeellisten kotikuntoutustutkimusten tulokset ovat olleet ristiriitaisia, eikä niiden perusteella ole vielä pystytty luomaan selkeitä suosituksia.

Tämän väitöskirjatutkimuksen tavoitteena oli tutkia yli 60-vuotiaiden kotona asuvien henkilöiden lonkkamurtuman jälkeistä liikkumiskyvyn palautumista ja siihen yhteydessä olevia tekijöitä sekä selvittää miten tuki- ja liikunta-

elimistön kipu ja leikkaustapa ovat yhteydessä liikkumiskyvyn vaikeuksiin ja fyysiseen inaktiivisuuteen. Lisäksi selvitettiin vuoden kestäneen yksilöllisesti suunnitellun moniosaisen kotikuntoutuksen vaikutuksia liikkumiskyvyn palautumiseen.

Tutkimus koostuu kahdesta tutkimusaineistosta jotka kerättiin Jyväskylän yliopiston Gerontologian tutkimuskeskuksessa yhteistyössä Keski-Suomen sairaanhoitopiirin sekä yhdeksän sairaanhoitopiirin kunnan kanssa vuosien 2004-2005 (Hip-Asymmetry) sekä 2008-2012 (ProMo) aikana. Hip-Asymmetry -tutkimukseen kuului 78 keskiäärin 75-vuotiasta lonkkamurtuman kokenutta henkilöä, joiden lonkkamurtumasta oli kulunut 8 kuukaudesta 7.5 vuotta. Tässä väitöskirjatutkimuksessa Hip-Asymmetry aineistosta käytettiin alkumittaus-aineistoa. ProMo -tutkimuksessa verrattiin liikkumiskyvyn palautumista edistävää kotikuntoutusta vallitsevaan kuntoutuskäytäntöön. Tutkimuksessa toteutettu vuoden kestävä yksilöllinen kuntoutusohjelma sisälsi mm. lihasvoima-, liikkuvuus- ja tasapainoharjoitteita, liikuntaneuvonnan, kotiympäristön turvallisuuden ja apuvälineiden arvioinnin sekä keskustelua kaatumisen pelosta sekä kivunhallinta keinoista. Tutkittavia seurattiin lonkkamurtumaleikkauksen jälkeisestä sairaalavaiheesta asti, ja kuntoutus aloitettiin heti kotiutumisen jälkeen. Tutkimukseen osallistui 81 keskimäärin 80-vuotiasta lonkkamurtumapotilasta, joista puolet sai tehostettua kotikuntoutusta.

Väitöskirjatutkimuksessa todettiin ulkona liikkumisen vaikeuksien lisääntyvän merkitsevästi lonkkamurtuman jälkeisen kymmenen viikon aikana. Lonkkamurtumapotilaista suuri osa päätyi ns. katastrofiseen kehityskaareen, jolloin liikkumiskyvyn vaikeudet lisääntyivät huomattavasti murtuman seurauksena ja ulkona liikkuminen vaikeutui edelleen kotiutumisen jälkeen. Suuri osa katastrofiseen kehityskaareen ajautuneista tutkittavista ei kyennyt vielä kuusi viikkoa kotiutumisenkaan jälkeen liikkumaan ulkona ilman toisen henkilön apua. Heillä oli ennen murtumaa ollut useammin käytössään liikkumisen apuväline ja heistä useampi oli kaatunut sisätiloissa ennen murtumaa. Lisäksi pidempi sairaalassaoloaika ja pitkittynyt alavartalon kipu olivat yleisempiä katastrofiseen kehityskaareen ajautuneilla. Tutkimuksessa todettiin myös, että tuki- ja liikuntaelimistön kipu on yleistä vielä vuosia murtuman jälkeen. Kovan alavartalokivun havaittiin olevan yhteydessä fyysiseen inaktiivisuuteen keskimäärin kolme vuotta leikkauksen jälkeen sekä leikkaustapaan keskimäärin kaksi vuotta leikkauksen jälkeen. Lonkkamurtumapotilaat, joiden lonkkamurtuma oli leikattu osteosynteesillä, kokivat enemmän alavartalokipua ja liikkumisvaikeuksia, kuin puoliproteesilla tai kokoproteesilla hoidetut henkilöt.

Lonkkamurtuman jälkeistä liikkumiskyvyn palautumista selvittäneen ProMo -tutkimuksen päätuloksena havaittiin, että vuoden kestävällä kotikuntoutusohjelmalla pystyttiin nopeuttamaan liikkumiskyvyn palautumista verrattuna vallitsevaan hoitokäytäntöön. Tutkimus osoitti, että kuntoutuminen tapahtuu toiminnan vaikeuksien kehittymisen teoreettisen mallin mukaan. Liikkumiskyvyn parantuminen porraskävelyssä 6 ja 12 kuukauden kuluttua kuntoutuksen aloittamisesta oli yhteydessä kolme kuukautta aiemmin mitattuun parantuneeseen tasapainoon. Osa kotikuntoutusohjelmaan osallistuneista henkilöistä koki jopa vähemmän vaikeuksia porraskävelyssä vuoden kuntoutuksen jälkeen kuin ennen murtumaa.

Tämän tutkimuksen tulokset osoittavat, että kohdennetulla ja tehokkaalla kuntoutuksella voidaan parantaa kotona asuvien lonkkamurtumapotilaiden liikkumiskykyä. Tutkimuksessa ei kuitenkaan selvitetty huonompikuntoisten laitoshoidossa asuvien lonkkamurtumapotilaiden kuntoutumista. Tutkimuksessa verrattiin itsenäisesti asuvien ikääntyneiden lonkkamurtumapotilaiden tehostetun kotikuntoutuksen vaikutuksia vallitsevaan perusterveydenhuollon avokuntoutuskäytäntöön Suomessa. Vastaavanlaisia tutkimuksia olisikin hyvä toteuttaa myös muiden maiden terveydenhuoltojärjestelmissä ja erilaisilla potilasryhmillä.

Tutkimustulosten perusteella voidaan todeta, että lonkkamurtuman jälkeistä liikkumiskykyä selittävät tekijät, kuten apuvälineen käyttö, kaatumiset ja liikkumiskyky ennen murtumaa, sekä leikkaustapa ja sairaalassaoloaika, tulisi huomioida entistä tarkemmin suunniteltaessa sairaalahoidon jälkeistä kuntoutusta. Tehokas kivunhallinta on myös tärkeää huomioida lonkkamurtumapotilaiden kuntoutuksessa. Vuoden kestäneen yksilöllisesti suunnitellun moniosaisen kotikuntoutuksen avulla liikkumiskykyä voidaan palauttaa kohti ennen murtumaa ollutta tasoa tai jopa paremmaksi. Lonkkamurtuman jälkeinen avokuntoutus tulisi olla tehostettua, progressiivista ja riittävän pitkäkestoista. Nykyisiä lonkkamurtuman käypähoitosuosituksia olisi hyvä tarkentaa sairaalahoidon jälkeisen kotikuntoutuksen osalta. Lisäksi liikkumiskyvyn palautumista tulisi seuranta sairaalasta kotiutumisen jälkeen. Tulevaisuudessa tutkimusta tulisi suunnata kuntoutuksen kustannustehokkuuden arvioimiseen sekä keskittyä tehokkaamman avokuntoutuksen juurruttamiseen käytäntöön.

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ORIGINAL PUBLICATIONS

I

THE TYPE OF SURGERY IS ASSOCIATED WITH PAIN AND PHYSICAL FUNCTION AMONG OLDER PEOPLE WITH PREVIOUS HIP FRACTURE: A CROSS-SECTIONAL CASE CONTROL STUDY

by

Anu Salpakoski, Mauri Kallinen, Ilkka Kiviranta, Markku Alen, Erja Portegijs, Taina Rantanen, Sarianna Sipilä

Submitted

II

PHYSICAL INACTIVITY AND PAIN IN OLDER MEN AND WOMEN WITH HIP FRACTURE HISTORY

by

Anu Salpakoski, Erja Portegijs, Mauri Kallinen, Sanna Sihvonen, Ilkka Kiviranta, Markku Alen, Taina Rantanen, Sarianna Sipilä

Gerontology 2011; 57 (1), 19-27. doi: 10.1159/000315490. Epub 2010 May 28.

III

PROMOTING MOBILITY AFTER HIP FRACTURE (PROMO): STUDY PROTOCOL AND SELECTED BASELINE RESULTS OF A YEAR-LONG RANDOMIZED CONTROLLED TRIAL AMONG COMMUNITY-DWELLING OLDER PEOPLE

by

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BMC Musculoskeletal Disorders

STUDY PROTOCOL Open Access

Promoting mobility after hip fracture (ProMo): study protocol and selected baseline results of a year-long randomized controlled trial among community-dwelling older people

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Abstract

Background: To cope at their homes, community-dwelling older people surviving a hip fracture need a sufficient amount of functional ability and mobility. There is a lack of evidence on the best practices supporting recovery after hip fracture. The purpose of this article is to describe the design, intervention and demographic baseline results of a study investigating the effects of a rehabilitation program aiming to restore mobility and functional capacity among community-dwelling participants after hip fracture.

Methods/Design: Population-based sample of over 60-year-old community-dwelling men and women operated for hip fracture (n = 81, mean age 79 years, 78% were women) participated in this study and were randomly allocated into control (Standard Care) and ProMo intervention groups on average 10 weeks post fracture and 6 weeks after discharged to home. Standard Care included written home exercise program with 5-7 exercises for lower limbs. Of all participants, 12 got a referral to physiotherapy. After discharged to home, only 50% adhered to Standard Care. None of the participants were followed-up for Standard Care or mobility recovery. ProMo-intervention included Standard Care and a year-long program including evaluation/modification of environmental hazards, guidance for safe walking, pain management, progressive home exercise program and physical activity counseling. Measurements included a comprehensive battery of laboratory tests and self-report on mobility limitation, disability, physical functional capacity and health as well as assessments for the key prerequisites for mobility, disability and functional capacity. All assessments were performed blinded at the research laboratory. No significant differences were observed between intervention and control groups in any of the demographic variables.

Discussion: Ten weeks post hip fracture only half of the participants were compliant to Standard Care. No follow-up for Standard Care or mobility recovery occurred. There is a need for rehabilitation and follow-up for mobility recovery after hip fracture. However, the effectiveness of the ProMo program can only be assessed at the end of the study.

Trial registration: Current Controlled Trials ISRCTN53680197

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Background

Fall-related injuries leading to hospitalization and activity restriction result in adverse health outcomes, mobility limitation and disability which may last years or become permanent [1-3]. For older people, hip fractures are among the most severe consequences of falls [4,5]. Hip fractures cause considerable health care costs during the first post fracture year [6-8]. The cost burden will double or even triple with the subsequent fall and fracture particularly if a home-dwelling person is admitted to permanent institutional care because of the fracture [8,9].

Community-dwelling older persons who survive a fracture need special attention. To cope at their homes safely sufficient mobility and functional ability is needed. Only 40% of hip fracture survivors recover to their pre-fracture ambulatory level and only 20% recover to the pre-fracture level in advanced mobility tasks [3,10]. Safe mobility and participation are challenged by persistent pain [11,12], fear of falling and balance impairments [13,14], lower limb muscle weakness [11], reduced bone mass and impaired bone geometry [15]. Consequently, older community-dwelling people recovering from a hip fracture are at an increased risk for a new fracture, persistent mobility limitation and disability as well as loss of independence in the near future.

Currently there is insufficient evidence on the best practices supporting recovery after hip fracture [16]. The current research knowledge is mostly based on efficacy driven research in which the effects of highly specified short-term interventions without follow-up have been investigated among a homogenous group of hip fracture participants. These studies have been performed under optimal conditions with specifically designed and arranged training protocols and facilities. Previous efficacy studies have shown that rehabilitation programs including intensive and supervised training sessions with resistance and balance training improve mobility [17-20], physical functioning [18-21] and level of physical activity [22] among older community living persons who have suffered a hip fracture. However, the effects on mobility disability remain unclear.

A rehabilitation program that produces significant effects in an efficacy study may not have same effects under real-world conditions [23]. Moreover, persons who are likely to benefit the most from a program including physical activity are usually excluded from these studies. Travelling to organized and supervised sessions on a weekly basis in a gym with the necessary set-up may be too demanding for many fracture patients [19,24]. Therefore, rehabilitation programs aiming to restore mobility after hip fracture need to be implemented and studied in the real-world conditions or close to that. Moreover, participants should not be excluded unless there is an empirical or ethical reason to do so (e.g. possibility for negative side effect of training or main outcomes are impossible to measure) [25]. Home-based individually tailored rehabilitation programs including weight-bearing exercises [26,27], exercises with progressive resistance [28] and a systematic follow-up and support [22] may form the most promising approach to increase the effectiveness of the rehabilitation to prevent mobility disability after hip fracture.

The Promoting Mobility after Hip Fracture (ProMo) study investigates the effects of a year-long individually tailored and home-based rehabilitation program compared to the Standard Care on mobility recovery, physical functional capacity and disability among over 60-year-old community-dwelling men and women who suffered a proximal femoral fracture. The purpose of this article is to describe the recruitment process, design and intervention as well as to present demographic baseline results of this randomized controlled trial.

Methods/Design

Context

All Finnish residents have health insurance. In Finland, municipalities are responsible for organizing specialized and primary health care for all people. For example, in Central Finland specialized care is provided by the Central Finland Central Hospital for 23 municipalities with a total population of 273 700. Each municipality organizes primary health care including inpatient rehabilitation, ward care and outpatient clinic for their residents at the local health care centers. After a proximal femoral fracture, patients living in Central Finland are operated at the Central Finland Central Hospital and transferred to the local health care centre of their municipality for inpatient care and rehabilitation typically within the first post-operative days. The inpatient rehabilitation period ranges from one week to few months depending on the health status and care needs.

Design

This study is a randomized controlled trial (RCT, ISRCTN53680197). Random allocation to the intervention (ProMo) and control (Standard Care) groups were performed after baseline measurements by the statistician, who was blinded to the study participants and their characteristics. The study group assignments were enclosed in sealed envelopes. Men and women and those operated with internal fixation or arthroplasty were randomized by blocks.

All participants were measured at the laboratory four times; at baseline, three, six and 12 months. After that all participants were followed-up for an additional year to collect data on form of dwelling, mobility limitation, physical functional capacity, mood and quality of life with a structured questionnaire. Study design is described in detail in Figure 1.

Pretrial power calculations were based on previously published longitudinal data on mobility recovery after hip fracture. In the study by Visser et al, 45.3% of the community-dwelling participants were independent in more demanding mobility tasks (chair rising, walking one block and negotiating stairs) before the fracture [10]. Twelve months after hip fracture less than half of them (20.7% of the total sample) had regained their pre-fracture level of mobility. The purpose of our study was to restore the pre-fracture level of mobility by the ProMo rehabilitation program. To detect the expected difference (based on percentages 45.3 and 20.7 from the study by Visser et al) between the study groups in mobility recovery at $\alpha = 0.05$ and $\beta = 0.20$, a minimum of 44 subjects was needed in each study group. Sample size was calculated using an online sample size calculator available from (DSS researcher's toolkit, http://www.dssresearch.com/KnowledgeCenter/toolkitcalculators/samplesizecalculators.aspx)

Participants and recruitment

Staff of the physiotherapy department of the Central Finland Central Hospital reviewed the medical records of all consecutive, over 60-year-old, ambulatory and community-dwelling men and women operated for femoral neck or pertrochanteric fracture (ICD code S72.0 or S72.1, http://www.cdc.gov/nchs/icd.htm) between 1.3.2008 and 31.12.2010 and living in the city of Jyväskylä or in nine neighboring municipalities. All patients fulfilling the inclusion criteria got an information letter on the study (n = 296). Of them, 161 patients expressed their initial interest in the study and were further visited by the ProMo representative during the inpatient period at the health care centre. Finally, 136 persons were recruited to the study. Patients living in an institution or confined to bed at the time of the fracture, suffering from severe memory problems (Mini Mental State Examination, MMSE < 18), alcoholism, severe cardiovascular, pulmonary or progressive (i.e neoplasm, ALS) disease, para-or tetraplegic or severe depression (Beck Depression Inventory BDI-II > 29) were excluded from the study. In total, 18 men and 63 women participated in the study. The flow chart of the study is shown in Figure 2.

Ethical issues

This project was approved by the Ethics Committee of the Central Finland Health Care District on December 18, 2007 (11/2007). Written information on the study was given to all participants. Participants signed an informed consent prior to participation. Proxy consent was not permitted. Those who were interested in the study had an opportunity to discuss with the researcher before signing the informed consent and giving a permission to review their medical records.

Measurements

Measurements and analysis will be performed blinded to the study group. Baseline measurements were organized as soon as possible after discharged to home; on average 70 (SD28) days after the hip fracture, 65 (21) days after the hip fracture operation and 42 (23, range 4-153) days after discharge to home. Measurements included a comprehensive battery of laboratory tests and self-report on mobility limitation, disability, physical functional capacity and health, as well as assessments for the key prerequisites of mobility, disability and functional capacity. All assessments were performed at the research laboratory.

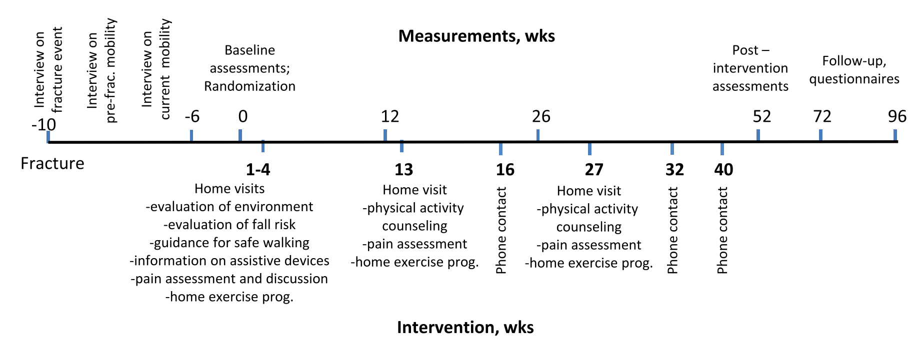

Figure 1 Study design.

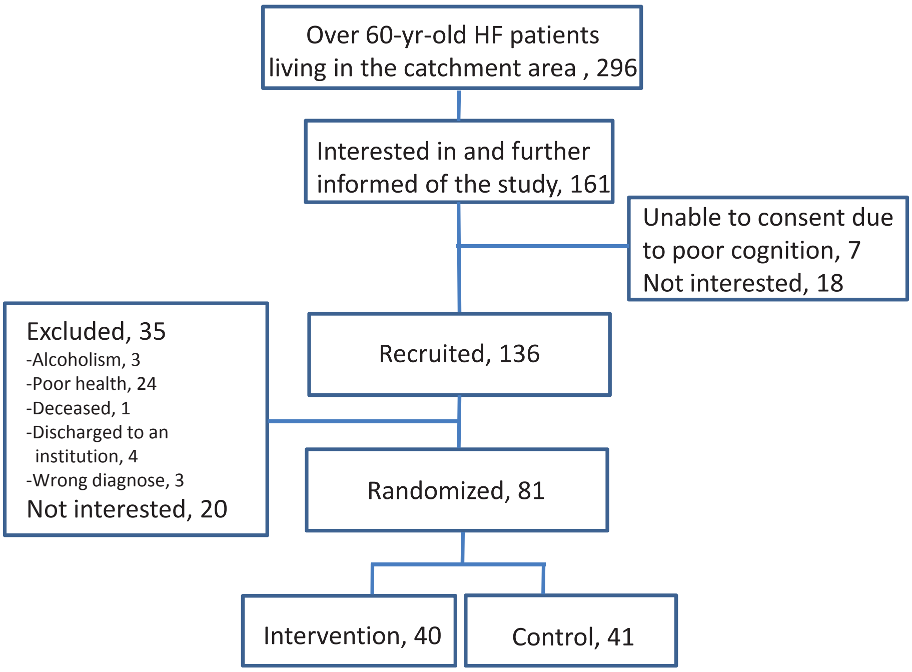

Figure 2 Participant recruitment flowchart.

Review of medical data and health status

Each participant was interviewed within 24 hours of the hip fracture with structured questions on the characteristics of the accident [29]. At baseline, during a medical examination performed by a nurse practitioner and a physician, the presence of chronic conditions, use of prescription medication, fracture status and date, type and date of surgery and lowest post-operation hemoglobin level during hospitalization were confirmed according to a pre-structured questionnaire, current prescriptions and medical records obtained from the local hospital and health care centers. To ascertain safe participation in the measurements and intervention, the physician evaluated contraindications according to ACSM guidelines [30] and acute conditions such as infections (e.g. acute respiratory or urinary tract infection) by blood count, C-reactive protein (hCRP) and hemoglobin (Hb) analysis. Cognitive status was assessed by Mini Mental State Examination (MMSE) [31], and depressive mood by Beck Depression Inventory (BDI-II) [32] at baseline. Self-rated health was determined by the question ''How would you describe your health?'' using a 4-point scale (very good, good, poor and very poor). Offending musculoskeletal pain in the low back, hip, knee, ankle and foot was assessed by a questionnaire. The question for the musculoskeletal pain was "Have you suffered from pain in the low back, hip, knee, ankle and foot region daily during the preceding month? Has the pain compromised your mobility?" Three alternative response options were: 1) no 2) yes, but the pain does not limit mobility 3) yes, the pain limits mobility.

Demographics, physical characteristics and living habits

Demographics included age, sex, living conditions, income and education. Body height and weight were measured using standard procedures and body mass index was calculated (body weight, kg/body height, m^2*100). Body composition was assessed with Bioimpedance devise with eight polar electrodes (BC-418, TANITA, Tokyo, Japan). Maximal hand grip strength was measured from the dominant hand with a dynamometer (Metitur Ltd, Palokka, Finland) and bone density and geometry with a peripheral computed tomography [15]. Current level of physical activity was assessed by a standardized question with slight modifications [33]. The question included seven alternative responses: 1) mainly resting 2) most activities performed sitting down 3) light physical activity twice a week at the most 4) moderate physical activity about 3 h a week 5) moderate physical activity at least 4 h a week or heavy physical activity ≤ 4 h a week 6) physical exercise or heavy leisure time activity several times a week and 7) competitive sports several times a week. No one reported participation in competitive sports. Responses were categorized as sedentary (1 to 3) and active (4 to 6). Smoking status was assessed with a questionnaire (never, former, current smoker).

Main outcomes

The short term primary outcome (at 3 and 6 mo) is Short Physical Performance Battery (SPPB) including 2.44 m habitual walking speed, five chair rises timed and standing balance tests [34]. One year primary outcome will be mobility limitation assessed by interviewing the subjects for the ability to getting in and out of bed, rising from a chair, walking across a room, walking one block, and climbing stairs [10]. In addition, self-reports of perceived difficulty in walking outdoors, walking 500 m, walking 2 km and climbing one flight of stairs will be assessed by a questionnaire. Secondary outcomes include physical disability (validated questionnaire) [35], health related quality of life (RAND-36), walking speed over 10 meters [36], isometric knee extension strength for both legs [36] (Metitur Ltd, Palokka, Finland), leg extension power with the Power Rig for both legs [11], functional balance (Berg Balance Scale) [37] and fear of falling (Activities-specific Balance Confidence scale) [38]. Information concerning use of formal and informal care and form of dwelling will be collected by a questionnaire.

Quality assurance

Our research centre has a long tradition and established methods on mobility and functional capacity assessments among older populations. A standard operation procedure was written before launching the study and then followed up carefully throughout the study. A system with periodical meetings and checks was set up for monitoring the quality of data collection. The personnel performing the measurements were carefully educated by a senior researcher. The same staff engaged in the data collection throughout the study except for the nurse practitioner who was replaced twice during the study. During the laboratory visits, all questionnaires were reviewed by the study coordinator. In case of missing information participants were asked to complete the questionnaire. If the participant was unable to come to the laboratory measurements at some point, self-reports were collected and Short Physical Performance Battery was performed at participants home.

Control condition; Standard care

At baseline, information on standard care after the hip fracture was collected by interviewing all participants with structured questions on advice and recommendations concerning rehabilitation they had received at discharge from hospital and/or health care centre. Seventy percent of all participants obtained a written home exercise program with no difference between the intervention and the control groups (68% vs. 71%, p = 0.813). From those who received a home exercise program, 70% exercised every day, 21% on weekly basis and 9% few times a month or not at all. Typically the program included five to seven exercises including ankle flexion and extension, knee flexion and extension, and hip abduction and extension in supine, sitting and/or standing positions with no additional resistance. None of the participants were followed up for the home exercises and the program was not updated. Of all participants 12 received a referral to physiotherapy (5 in the intervention and 7 in the control group) while the rest did not get any further instructions regarding rehabilitation.

ProMo -Intervention

Intervention includes standard care and ProMo-program which aims to restore mobility after hip fracture. The intervention starts after baseline measurements (Figure 1). ProMo is an individually tailored year-long physical activity and rehabilitation intervention taking place at participants' homes. It includes five to seven home visits by an experienced physiotherapist; the first three visits will be performed within one month followed by a visit three and six months after baseline measurements. If necessary, an additional visit two months after baseline will be performed. The scientific basis for the ProMo arises from a previous systematic review on fall and fracture prevention [39] and interventions that successfully prevented functional decline [26,40] among community-dwelling high risk groups of older people. ProMo comprises two partly overlapping phases. Phase I prepares the basis for the physical rehabilitation and physical activity. The content of Phase I is as follows: 1) Evaluation and modification of environmental hazards known to increase falls risk [41] 2) Guidance for safe walking including readjustment of walking aids and information on shoes and anti-slip shoe devices for icy conditions. In addition, written information on assistive devices and a brochure on hip protectors will be provided. All above mentioned information and brochures have been published before and are available for laypersons as well as for health care professionals 3) Pain assessment and discussions on pain relief strategies that the participants have perceived effective. Regular pain assessment and information on pain management are independently associated with better pain relief in hospitalized patients [42]. Pain assessments will be repeated three and six months after baseline measurements.

Phase II includes a progressive home exercise program and physical activity counseling. The exercise program comprises strengthening exercises for the lower limbs, balance training in standing position, walking exercises and stretching. The program will be delivered during the second home visit and it will be updated to a more challenging one during each following home visit. Accordingly, during the ProMo -intervention five written, progressive and individually tailored home exercise programs of approximately 30 minutes duration and designed by the PhysioTools software (PhysioTools, Tampere, Finland) will be delivered. Strengthening and stretching exercises will be performed three times a week and balance and walking exercises on two to three other days in the week. During the intervention, the resistance for the strengthening exercises will be individually increased with resistance bands with three different strengths.

An individual motivational face-to-face physical activity counseling session [43,44] will be scheduled approximately three months after the baseline measurements. The average duration of this session is 30 minutes. The topics covered during the counseling session include the level of physical activity and participation in physical exercise before the fracture, the persons' interest in returning to previous activities, beginning physical activity or exercise, the willingness to be active in everyday chores, to exercise on one's own or to participate in supervised exercise classes. The problem-solving method will be used to address perceived obstacles to physical activity and to access exercise facilities offered by the municipality. Preexisting written information on the supervised physical activity classes and exercise facilities offered by the municipality will be given. Based on this information, the participant and the physiotherapist together design a personal physical activity plan, which will be signed during the session. After the first face-to-face counseling session, the physiotherapist will support compliance to the program and the behavior change through three phone contacts and one face-to-face session with 1-2 months interval. All participants in the intervention group will keep a physical activity diary on home exercises and physical activities.

Data analysis

Means, standard deviations and frequencies for the demographic variables were calculated. Normality of the distributions was tested with Shapiro-Wilkinson test. The significance of differences between the intervention and control group was tested by cross-tabulation and chi-square tests in the case of discrete variables, by Student's t-test for independent samples for normally distributed data and by Mann-Whitney U-test for non-normally distributed continuous data. Association between variables was analyzed using Pearson correlation coefficient. Determinants for mobility limitation and physical disability will be assessed by linear and logistic regression analysis and the theoretical pathway to mobility limitation and physical disability by structural equation modeling. The effects of ProMo will be assessed by intention-to-treat principal using repeated measures ANOVA, covariance analysis and linear mixed models for continuous variables and by general estimation equation for categorical variables.

Characteristics of the participants

Table 1 summarizes the demographics, physical characteristics, health, living habits, fracture status and the type of operation in the total sample and in the intervention and control groups. No significant differences were observed in any variable between the study groups.

The mean age of the participants was 79 (SD ± 7) years and 78% of the participants were women. More than half of the subjects were living alone. Poor self-rated health was reported by 41% of the total sample. The average number of chronic diseases was 3 ± 2. The mean MMSE value was 26 ± 3 and that of the BDI-II 9 ± 6. Offending pain in lower back, hip or knee region on the fractured side was reported by 46% of the participants. The corresponding value for the non-fractured side was 37%. Nine percent of the participants were current smokers and 92% were rated sedentary.

The majority of the participants (n = 71/81) fell from standing height. Six were able to break the fall e.g. with an outstretched arm. More than half (n = 43) fell indoors and from those 34 participants fell at home. Fifty two participants suffered a femoral neck and 29 a pertrochanteric fracture. Fracture was operated with internal fixation in 38 and with arthroplasty in 43 participant.

Discussion

The baseline results of our randomized controlled trial emphasize that there is an urgent need to develop long-term rehabilitation strategies for mobility recovery and prevention of mobility disability after hip fracture. According to the patients' own report, only half of them received a home exercise program and followed up the instructions given by the health care personnel on a daily basis. Home exercise programs were not updated and programs did not include any external resistance, walking or balance exercises. Less than 15% of the participants were referred to physiotherapy, while the rest did not get any further instructions or follow-up for recovery of mobility and functional capacity.

Previous studies have shown poor mobility recovery after hip fracture and some of the studies suggest that this phenomenon may turn out to be permanent [1,10,45]. Poor lower limb muscle strength, postural balance and hip pain are associated with poor mobility recovery after hip

Table 1 Demographics, health and hip fracture status among over 60-year-old men and women after a recent hip fracture (Mean ± SD, frequency)

	All (n = 76-81)	ProMo (n = 38-40)	Control (n = 38-41)	p*
Age, yr	79 ± 7	80 ± 8	79 ± 6	0.251
Body height, cm	160.6 ± 8.9	160.9 ± 8.9	160.3 ± 9.1	0.785
Body weight, kg	65.8 ± 11.5	65.8 ± 11.9	65.9 ± 11.3	0.968
BMI	25.5 ± 3.8	25.3 ± 3.6	25.6 ± 3.9	0.710
Poor self-rated health, %	41	43	39	0.823
Number of chronic diseases, n	3 ± 2	3 ± 2	3 ± 2	0.581
MMSE	26 ± 3	26 ± 3	26 ± 3	0.686
BDI-II	9 ± 6	9 ± 6	8 ± 6	0.335#
hCRP at baseline	7.7 ± 9.9	8.4 ± 11.1	7.1 ± 8.6	0.855#
Hb at baseline, g/l	128.7 ± 12.9	127.4 ± 12.7	130.1 ± 13.1	0.351
Lowest Hb after operation, g/l	98.0 ± 13.2	97.5 ± 11.1	98.5 ± 15.0	0.795#
Smoking, %				0.382
- Never	79	85	73	
- Former	12	10	15	
- Current	9	5	12	
Living alone, %	59	60	59	1.000
Level of education Elementary school or less, %	49	54	44	0.502
Income, €/month	1363 ± 828	1321 ± 637	1408 ± 998	0.965#
Physical activity, % Sedentary	92	95	90	0.675
Fracture status				
Fall related fracture, %	88	90	85	0.737
Site of fracture, %				0.645
- Femoral neck	64	68	61	
- Pertrochanteric	36	32	39	
Type of operation, n				0.719
- Internal fixation	38	19	19	
- Hemiarthroplasty	33	15	18	
- Total arthroplasty	10	6	4	

*Independent t-test for normally distributed continuous variables, Chi-square for discrete variables

#Mann-Whitney U for non-normally distributed continuous variables

fracture [10,45]. Muscle strength deficit on the fractured side is associated with greater pain on the fractured compared to the non-fractured side [11] and large muscle strength deficit is associated with mobility limitation and balance impairment [46]. Some recovery is expected to occur during the first six months after hip fracture. However, our earlier study showed that community-dwelling older men and women who had suffered a hip fracture on average four years earlier were significantly weaker, had a significant side-to-side difference in lower limb muscle strength [11,15] and had significantly impaired postural balance and balance confidence [14] compared to the age and sex matched controls with no major lower limb injuries. The presence of multiple impairments, pain and poor balance confidence (fear of falling) strongly suggest increased and cumulative risk for loss of mobility in the near future if targeted rehabilitation with follow-up for mobility recovery is not available.

The standard care, in this study, did not include the follow-up for mobility recovery. It included home exercise programs with five to seven exercises mostly for the fractured limb. Programs were not updated to a more challenging one and no additional resistance was used. None of the participants were followed-up for the home exercise program. Variation in the rehabilitation activities and lack of guidelines for mobility limitation and disability prevention after hip fracture has been recognized worldwide [47,48]. It has been suggested that better functional outcomes could be achieved with more intensive rehabilitation and promotion of physical activity after hip fracture [47,48].

The aim of the ProMo -intervention is to restore mobility after hip fracture and it was firmly grounded to existing research literature. As we wanted to include all hip fracture patients who could potentially benefit from the rehabilitation, also the weakest and the oldest ones, the program was designed to take place at the participants' home. The ProMo is a 1-year progressive physical exercise and physical activity counseling program reinforced by advise, support and encouragement for safe walking as well as discussions on fall prevention and pain management strategies. Pain assessment and fear of falling management was regarded as an essential part of the program as older people who had had a hip fracture suffer from residual pain [12,49] and fear of falling [14]. Both pain [12,50,51] and fear of falling [52-54] have been independently associated with mobility limitation, activity restriction, low physical functioning and falls among older populations. To our knowledge and based on a recently updated Cochrane review [16] there is no previously published effectiveness RCT among community-dwelling hip fracture participants including a home-based intervention specifically targeting on mobility recovery and which has mobility limitation and disability as the main outcome. Encouraging evidence on effects of interventions with similar components on the level of physical activity [22], functional capacity [26] and health related quality of life [55] have, however, been reported.

The recruitment process of this study included eligibility screening in multiple phases and there was close collaboration with clinicians at the local hospital and health care centers. In total, 296 patients who fulfilled the inclusion criteria were identified and informed about the study at the hospital. From those approximately half (n = 161) were interested in and further informed about the study. From those who expressed initial interest 84% (n = 136) signed informed consent and were enrolled in the study. This was regarded as a sufficient number of participants, allowing a 35% attrition rate, ending with 44 in each study group. Because our participants were recruited at the clinic (health care centre) prior to discharge to home, we set our safety margin in the attrition rate higher than 20% which was recommended by Ferrucci et al in their consensus report [56]. We expected some changes in health status, living conditions and willingness to participate to occur already before the baseline measurements. Accordingly, 26% were further excluded due to poor health, alcoholism and living conditions and 15% declined participation mostly due to poor self-rated health and tiredness (Figure 1). Finally, 81 men and women were assessed at baseline and randomly assigned into ProMo -intervention and control groups. Despite of careful planning of the study and target of the recruitment period from 24 to 33 months, we did not completely reach the estimated number needed for this study. However, as the intervention is home-based and individually targeted and the main outcomes can be assessed at the participants' home, we trust that the additional drop-out will be small. The demographics of our study participants is comparable to earlier studies involving community-dwelling older people recovering from hip fracture; the majority of them are women and the mean age is close to 80 [57].

In conclusion, this report summarized the rationale, procedures and intervention of a 1-year RCT with 1-year follow-up on the effectiveness of home-based rehabilitation program aiming to restore mobility after hip fracture among community-dwelling over 60-year-old men and women. The special feature of the current study is that we reinforce the home exercise program by advice, support and encouragement for safe walking and discussions on fall prevention and pain management strategies. In addition, promotion of using existing exercise and rehabilitation services available for older people in their own community was performed by physical activity counseling. These facilities will be available for the participants also after finishing the project. This intervention study will provide knowledge of the rehabilitation for mobility recovery among community-living older people after hip fracture. However, the effectiveness of the program can only be assessed after the end of the study.

Abbreviations

BDI-II: Beck Depression Inventory; BMI: Body Mass Index; Hb: Hemoglobin; hCRP: C-reactive protein; MMSE: Mini Mental State Examination.

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Authors' contributions

SS developed the idea of conducting the study, recruited the participants, collected and analyzed the data, interpreted the results and wrote the paper. AS recruited the participants, collected the data and wrote the paper. JE collected the data and wrote the paper. AH conceived the idea of the study, interpreted the results and wrote the paper. MAK analyzed the data and wrote the paper. MA-K conceived the idea of the study, recruited the participants, interpreted the results and wrote the paper. SES collected the data, interpreted the results and wrote the paper. MP conceived the idea of the study, recruited the participants, interpreted the results and wrote the paper. TR conceived the idea of the study, interpreted the results and wrote the paper. MK conceived the idea of the study, recruited the participants, collected data, interpreted the results and wrote the paper. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

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IV

WALKING RECOVERY AFTER A HIP FRACTURE: A PROSPECTIVE FOLLOW-UP STUDY AMONG COMMUNITY-DWELLING OVER 60-YEARS OLD MEN AND WOMEN

by

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Research Article

Walking Recovery after a Hip Fracture: A Prospective Follow-Up Study among Community-Dwelling over 60-Year Old Men and Women

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Purpose. Recovery of walking outdoors after hip fracture is important for equal participation in the community. The causes of poor recovery are not fully understood. This study investigates recovery of walking outdoors and associated determinants after hip fracture. *Methods*. A prospective follow-up study, among clinical sample of 81 community-dwelling hip fracture patients over 60 years. Perceived difficulty in walking outdoors and 500 meters was assessed before fracture, at discharge to home (3.2 ± 2.2 weeks after surgery), and on average 6.0 ± 3.3 weeks after discharge. Potential determinants for walking recovery were assessed. Linear latent trajectory model was used to analyse changes during follow-up. Association between walking trajectories and potential determinants was analysed with a logistic regression model. *Results*. Two trajectories, No-to-minor-difficulty and Catastrophic, were found. Thirty-eight percent of the participants ended up in the Catastrophic trajectory for walking outdoors and 67% for 500 meters. Multivariate logistic regression analysis revealed that use of walking aid and indoor falls before fracture and prolonged pain were independently associated with catastrophic decline in both primary outcomes: difficulty in walking outdoors and 500 meters. *Conclusions*. A large proportion of community-dwelling older people recovering from hip fracture experienced catastrophic decline in outdoor walking. Acknowledging recovery prognoses at early stage enables individualized rehabilitation.

1. Introduction

Poor recovery after hip fracture causes considerable suffering for the patients and imposes a financial burden on the social and health care sector. Recovery of walking ability after hip fracture is a necessity for reestablishing patients into their normal environment. The causes of poor recovery are not fully understood. A few studies have investigated walking recovery after the hip fracture [1–3]. Taylor et al. [3] reported that, during inpatient rehabilitation, on average four weeks after hip fracture, patients experienced improvement in walking ability and physical factors, independent of pain or balance. However, on average three months after discharge, they reported pain, poor balance, and fear of falling, as well as reduced outdoor mobility, walking ability, and participation in community activities.

Moving outdoors is essential for the independence of community-dwelling older people. Difficulties in walking outdoors raise inequality issues as sufficient walking ability is needed for the access to public services and participation in the community. Therefore, it is important to eliminate all the barriers for outdoor walking [4]. The ability to walk even a short distance outdoors can be meaningful for successful and independent living at home. Moreover, among persons with walking limitations, outdoor activities might help to maintain physical functioning [5].

At discharge from the hospital, community-dwelling hip fracture patients usually receive a written home exercise program. However, neither compliance with the program nor mobility recovery after the fracture is systematically followed up [6]. The first weeks after hip fracture have been found to be critical for the recovery. But the lack of supported discharge, long-term follow-up, and planned individualized long-term rehabilitation is acknowledged [7].

The aim of this study was to investigate recovery of walking outdoors within the first ten weeks after hip fracture among over 60-year-old community-dwelling men and women. In addition, we explored the determinants associated with the different walking trajectories after hip fracture.

2. Materials and Methods

2.1. Participants. This study utilizes baseline data of a randomized controlled trial (ISRCTN53680197). This is a prospective follow-up design covering on average the first ten post hip fracture weeks and retrospective data on prefracture walking difficulties. A detailed description of the study design and recruitment of the participants has been published earlier [6]. Briefly, the medical records of hip fracture patients were reviewed between 1.3.2008 and 31.12.2010. All patients fulfilling the inclusion criteria (>60 years, ambulatory, community-dwelling, operated for femoral neck or trochanteric fracture, and living in the ten municipalities in Central Finland) were informed about the study during the inpatient period after surgery ($n = 296$). Of those, 161 were interested in the study and were further visited by one of the researchers. Finally, 136 persons were recruited. Patients suffering from severe memory problems (MMSE < 18), alcoholism, severe cardiovascular, pulmonary, or a progressive disease, or severe depression (BDI-II > 29) were excluded. In total, 81 persons participated in the study.

2.2. Ethical Approval. The study was conducted in accordance with the ethical principles stated in the Declaration of Helsinki. The ethical committee of the Central Finland Health Care District approved the study (K-Sshp Dnro56/2007). All participants gave their written informed consent prior to participating in the study.

2.3. Measurements. The primary outcomes of the study, self-reported difficulties in walking outdoors and 500 meters, were assessed at three different time points: (1) before fracture elicited at the hospital on average 10 ± 5 days after fracture, (2) at discharge from the hospital or health care centre, and (3) 6 ± 3 weeks after discharge to home. The questions were formulated as "Do you have difficulty in walking outdoors/500 meters?" with the following response options: (1) able to manage without difficulty, (2) able to manage with some difficulty, (3) able to manage with a great deal of difficulty, (4) able to manage only with the help of another person, and (5) unable to manage even with help. For the trajectory analyses, options 4 and 5 were combined due to the low response frequencies in the latter category.

2.3.1. Prefracture Information. Demographics and chronic diseases present for at least three months were collected from the medical records of hospital and health care centres. The comorbidity was calculated as the number of chronic diseases. In addition, diagnoses of the osteoarthritis, osteoporosis, and diabetes were reported. Use of walking aids outdoors and falls indoors and outdoors during the previous year were collected with a questionnaire during the inpatient period. Falls were dichotomised as "no falls" and "one or more falls".

2.3.2. Hospital Information. Hip fracture diagnosis, type of surgery, and the lowest haemoglobin value after surgery were collected from the medical records. Type of surgery was categorised as fixation (internal fixation of femoral neck and extra-/intramedullary fixation of trochanteric fracture), hemiarthroplasty and total hip replacement. Time from fracture to surgery, duration of inpatient period and time from discharge to laboratory assessments are reported.

2.3.3. Information at Discharge. As early mobilization after hip fracture is associated with walking recovery [8], we assessed perceived difficulties in walking at the hospital ward. The question was formulated as follows: "How do you manage moving around in the ward?" The response options were (1) able to manage without difficulty, (2) able to manage with some difficulty, (3) able to manage with great deal of difficulty, (4) able to manage only with the help of another person, and (5) unable to manage even with help. These were dichotomised into "no difficulty" (1) and "difficulty" (2)–(5). Moving-related pain on the fractured side was assessed with the question "Do you have offending pain in the low back/hip/knee on the fractured side which impairs your moving?" Pain was considered moving related if it affected moving in at least one of the sites at discharge. The presence of chronic diseases and use of prescription medication, including painkillers, were confirmed according to a prestructured questionnaire, prescriptions, and medical records.

2.3.4. Information 6 Weeks after Discharge. The physical performance measurements were performed in the research laboratory. Contraindications for safe participation were evaluated by a physician [9].

Functional balance was measured using the Berg Balance Scale [10], which evaluates an individual's ability to perform different tasks related to the skills of sitting down, standing up, reaching, turning around, looking over one's shoulder, and one-foot standing. The ability to perform each of the 14 tasks is rated from 0 (incapable) to 4 (safe and independent). The maximum score is 56, and higher scores indicate better functional balance.

Maximal isometric knee extension force was measured in the fractured and nonfractured side using an adjustable dynamometer chair (Good Strength, Metitur LTD, Palokka, Finland). In the statistical analysis knee extensor force was adjusted with the body weight. The ankle was attached to a strain-gauge with the knee angle fixed at 60 degrees from full extension. The leg was extended as forcefully as possible and participants were encouraged to make a maximal effort during the measurement. The measurement was repeated at least three times until no further improvement occurred. The best performance was used in the analysis. Maximal isometric handgrip force of the dominant hand was measured using an adjustable dynamometer chair (Good Strength, Metitur LTD, Palokka, Finland). The dynamometer was fixed to the arm of the chair with the elbow angle of 90 degrees. The handle was squeezed as hard as possible and the measurement was repeated at least three times until no further improvement occurred. The best performance was used in the analysis.

The amount of pain in the low back, hip, and knee region on both sides of the body during the last week was assessed with the Visual Analog Scale (VAS) [11]. A 100 mm line without numbers was used. A summary index was calculated from all six VAS variables. Body weight was measured in kilograms and height in centimetres.

2.4. Statistical Analyses. For trajectory analysis the growth mixture model approach was used, which permits the identification of population subgroups following similar recovery trajectories and separates them from other subgroups. The key property of the approach is that the subgroups are not known in advance, but their presence is inferred from the data. A mixture model includes two (or more) latent groups, whose trajectory parameters are estimated simultaneously together with each individual's probabilities of belonging into these groups. The membership probabilities can be used to describe the clarity of differences between the two groups via the summary statistic entropy, which ranges between zero and one, where a value close to one indicates an unambiguous grouping [12]. Growth mixture models have recently been used in the analysis of trajectories of various variable types [13–17] but less for ordered-category outcomes. Within the latent subgroups a growth model was fitted to the data while allowing the model growth parameters to vary over the latent groups. Within latent class g $(g = 1, 2)$, the (scaled) threshold structure of the response variables within time-point i $(i = 1, \ldots, 3)$ and response category j $(j = 1, \ldots, 3)$ was modeled according to

$$y_{(G)ij} = \mu_G + 0.1c_i\beta_1 + (0.1c_i)^2\beta_2 + c_j b_{ij}\tau_i, \qquad (1)$$

where μ is the grand mean and β_1 and β_2 are the linear and quadratic growth coefficients, respectively. The coefficient τ describes the separation of the categories within the time points, and we permitted the separation to vary according to time by estimating threshold-specific factor b. At the first time point we fixed b to one for the first response category within the latent groups to establish this as the reference category. The design vector $c = (-1, 0, 1)$ represents the time point-specific contrast. This model structure enables the structure of the trajectories to be separated into growth parameters, both linear and quadratic, as well as other types of differences in the response probabilities, which we will refer to as nonlinear. The maximum likelihood estimator used in the analyses permitted retaining the participant in analysis, if there was a nonmissing measurement from at least one time point.

Due to the small sample size we employed a three-stage strategy in the analysis of the walking recovery data. First, a growth mixture model was performed. Secondly, we compared the trajectory group differences for each determinant individually using the nonparametric median test for continuous variables and the chi-square test for discrete variables. Nonparametric tests were used because of nonnormality of the continuous measures. Thirdly, logistic regression modeling was performed to assess determinants, which were individually associated with walking trajectories. Determinants which differed significantly between the trajectories were included into the model, except for the frequency of osteoarthritis in walking 500 meters. We observed that logistic regression with osteoarthritis as a predictor led to quasi-complete separation, where the maximum likelihood parameter estimate does not exist [18]. The problem is due to the frequencies of diagnoses of osteoarthritis in the lower extremity: 19% in the Catastrophic trajectory group and none in the No-to-minor trajectory group. In Model I each determinant was a single regression of the probability of being included in the Catastrophic trajectory group. In Model II the Catastrophic trajectory group probability was predicted by all statistically significant variables at the study time points (before fracture, discharge, six weeks after discharge). All models were adjusted for age and gender. In addition, the C-statistic was calculated and used as the discrimination index in the fully adjusted logistic regression models.

The trajectory models were fitted with the Mplus-program (version 6; Muthén & Muthén 2011). Descriptive statistics and group comparisons were carried out using the R-environment (version 2.12.2; R Development Core Team 2011). The chi-square tests of independence were performed using the R-package gmodels (version 2.15.1), C-statistics with R-package rms (version 3.6.3), and logistic regression with IBM SPSS Statistics for Windows (version 19.0; Armonk, NY:IBM Corp.).

3. Results

Sixty-three (78%) of 81 participants were women and the average age was 80.0 ± 7.1 years. Fifty-two participants (64%) had a femoral neck fracture and 29 a trochanteric fracture. Time from fracture to surgery was on average 3 ± 4 days, duration of inpatient period 3.2 ± 2.2 weeks, and time from discharge to the laboratory assessments 6.0 ± 3.3 weeks.

Walking outdoors and walking 500 meters were assessed from 79 (98%), 73 (90%), and 81 (100%) participants in the three measurement waves. In walking outdoors ($P < 0.001$) and walking 500 meters ($P < 0.001$), the parametric bootstrapped likelihood ratio test [19] indicated that two groups were more likely than one to account for the difficulty trajectories. We called these trajectories the No-to-minor-difficulty and Catastrophic trajectories. It is noteworthy that

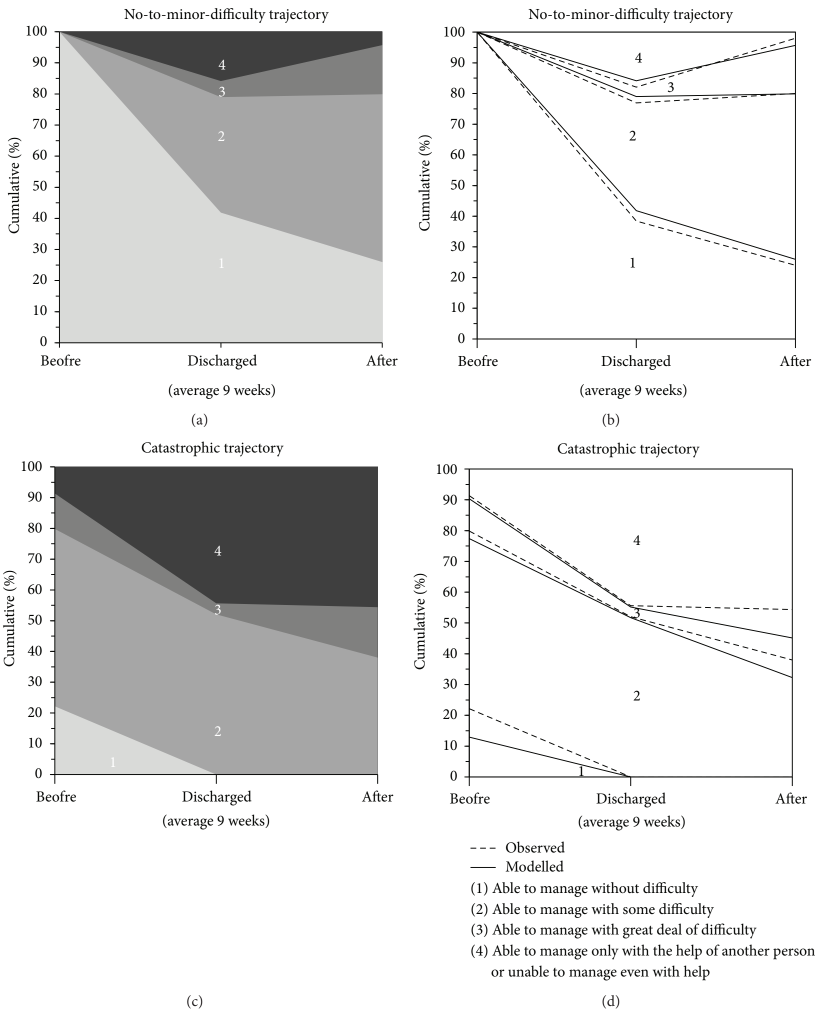

Figure 1: Trajectories for walking outdoors. The figures show the cumulative percentage of individuals within a response category at the three time points. Upper ((a)-(b)) No-to-minor-difficulty trajectory and lower ((c)-(d)) Catastrophic trajectory. Panels (b) and (d) show amount of participants actually observed and modelled.

mobility difficulties increased in both groups and, among majority of the participants, recovery to the prefracture state was not observed.

3.1. Walking Outdoors. Figure 1 shows the trajectories for difficulties in walking outdoors (entropy: 0.73), along with the cumulative percentage of individuals within a response category at each of the three time points. We found that in the No-to-minor-difficulty trajectory ($n = 50$) there was a curvilinear development (linear $P = 0.003$; quadratic $P = 0.004$), which is seen as initial drop in and levelling-off of the cumulative percentages. This trajectory included participants with no prefracture mobility difficulties. At discharge, 42% of them and at six weeks thereafter 26% reported no

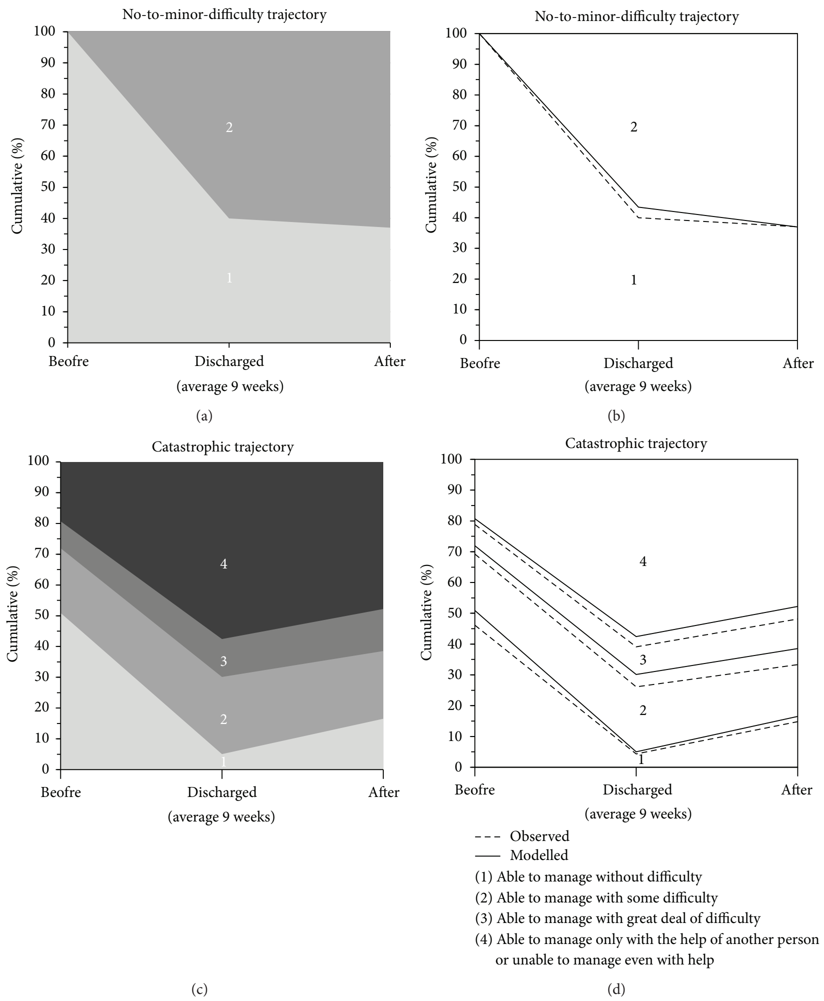

Figure 2: Trajectories for difficulties in walking 500 meters. The figures show the cumulative percentage of individuals within a response category at the three time points. Upper ((a)-(b)) No-to-minor-difficulty trajectory and lower ((c)-(d)) Catastrophic trajectory. Panels (b) and (d) show amount of participants actually observed and modelled.

difficulties in walking outdoors. In the Catastrophic trajectory ($n = 31$), we observed linear worsening ($P = 0.001$) over time. Twenty-two percent of the participants in the Catastrophic trajectory reported no difficulties before fracture. Mobility difficulties increased at discharge and continued to increase six weeks thereafter. Nearly half of the participants in the Catastrophic trajectory needed help of another person in walking outdoors at discharge (44%) and at 6 weeks after discharge (46%).

3.2. Walking 500 Meters. Figure 2 shows the cumulative percentages of the trajectory model for difficulties in walking 500 meters (entropy: 0.78). Overall, the No-to-minor-difficulty trajectory ($n = 27$) had low reported levels of difficulties, and the trajectory structure was explained by linear decline ($P = 0.007$). None of the participants in the No-to-minor-difficulty trajectory had prefracture walking difficulties. At discharge, 57% and six weeks thereafter 63% of the participants reported some difficulties. In the Catastrophic trajectory group we observed a curvilinear development (linear $P < 0.001$; quadratic $P = 0.004$). In the Catastrophic trajectory, 19% were unable to walk 500 meters without the help of another person before fracture. Perceived difficulties increased dramatically after the fracture, as at discharge 58% and at 6 weeks after discharge 48% needed the help of another person.

3.3. Differences in the Trajectory Groups. Underlying determinants associated with the trajectories in walking outdoors (Table 1) were higher frequencies in the use of walking aids and indoor falls during the previous year, longer hospitalisation period, and more offending pain at discharge in the Catastrophic compared to the No-to-minor-difficulty group. At six weeks after discharge, the participants in the Catastrophic trajectory reported significantly more pain in the lower body than those in the No-to-minor-difficulty trajectory. Compared to the participants in the Catastrophic trajectory, functional balance was better and the knee extensor force of the non-fractured side greater in the No-to-minor-difficulty trajectory, reflecting worse overall physical function in the Catastrophic trajectory weeks after returning to live in the community.

Participants using walking aids before fracture had nearly eight times the risk, those who fell indoors prior to the fracture nearly four times the risk, and those suffering from offending pain at discharge nearly six times the risk for Catastrophic trajectory, compared to those who had no walking aids or who had not fallen indoors before fracture or who did not suffer from pain at discharge. In addition, longer inpatient period and pain six weeks after the discharge were significantly associated with ending up in Catastrophic trajectory.

In walking 500 meters (Table 2), the participants in the Catastrophic trajectory were older than those in the No-to-minor-difficulty trajectory. The prefracture use of walking aids, indoor falls, and lower extremity osteoarthritis were more common among the Catastrophic trajectory group. Time from surgery to discharge was longer among the participants in the Catastrophic trajectory compared to the No-to-minor-difficulty trajectory group. Six weeks after discharge, the participants in Catastrophic trajectory reported more pain in the lower body and had poorer functional balance than those in the No-to-minor-difficulty trajectory. Logistic regression analyses revealed that the risk for Catastrophic trajectory was nearly six times greater among those who used walking aids before fracture and nearly five times greater among those who fell indoors before fracture compared to those with no walking aids or indoor fall history pre-fracture. Additionally, longer inpatient period and pain six weeks after the discharge were associated with risk for ending up in Catastrophic trajectory.

4. Discussion

At six weeks after discharge to home from the inpatient period, the participants of this study reported severe difficulties in walking outdoors. Two trajectories for the recovery of walking outdoors and 500 meters were found: No-to-minor-difficulty trajectory and Catastrophic trajectory. The No-to-minor-difficulty trajectory included participants with no pre-fracture walking difficulties, followed by some difficulties after fracture. Majority of the participants in the Catastrophic trajectory had prefracture outdoor walking difficulties followed by a steep decline after fracture. The underlying determinants associated with the Catastrophic walking trajectories were use of walking aids and indoor falls before the fracture, length of the inpatient period, offending pain on the fractured limb at discharge, and prolonged lower body pain.

Our results are in line with the previous studies showing that walking recovery after the hip fracture is challenging [2, 20, 21]. We observed that, on average, six weeks after returning home, the majority of the participants reported difficulty in walking outdoors and 500 meters and nearly half of the participants in the Catastrophic trajectory needed the help of another person. A large proportion of older community-dwelling people recovering from hip fracture, are home bound and immobile [22]. During the recovery process, the first steps outside the home may be taken at the porch, patio, backyard, or driveway. Walking for a longer distance, such as 500 meters or one block is, however, necessary for participation in common societal activities such as use of services, shopping, or leisure time activities. According to our results, approximately two-thirds of the participants did not end up in catastrophic decline in outdoor walking ability and were thus able to return to outdoor activities near home with minor difficulties. However, two-thirds of the participants experienced a catastrophic decline in the ability to walk 500 meters suggesting severe difficulties in returning to community activities after hip fracture. These results suggest that current rehabilitation strategies do not sufficiently take into account the prerequisites for safe walking and the ability to return to community activities. In addition, we know that difficulty or the inability to walk outdoors increases the risk for dependence and institutionalization [23]. Hip fractures cause considerable health care costs during the first postfracture year [24–26]. The cost burden can double or even triple if a home-dwelling person is admitted to permanent institutional care because of a fracture [26, 27].

Characterization of the determinants associated with poor outdoor walking recovery after hip fracture is important. Previous knowledge on walking recovery in general is fragmentary and the factors associated with poor recovery of walking outdoors have been even less investigated. Previous studies suggest that prefracture use of walking aids [1, 28], high age [29, 30], handgrip strength at admission to hospital [31], and longer inpatient period [32] predict recovery of the physical function after hip fracture. In the present sample, some of the determinants associated with increased difficulty in walking outdoors were present before the fracture. The individuals in the Catastrophic trajectory were more often

Table 1: Characteristics of participants by walking trajectories in walking outdoors (n, mean ± SD, median P value/n (%), χ^2 P value) and binary logistic regression model for statistically significant variables as a predictor for catastrophic trajectory.

	Trajectory					Binary logistic regression	
	No-to-minor-difficulty n = 50		Catastrophic n = 31		P value	Model I[e]	Model II[f]
	n		n			OR (95% CI)	OR (95% CI)
Demographic and prefracture information							
Age	50	78.6 ± 7.2	31	82.2 ± 6.5	*0.362*		
Women (%)	50	42 (84)	31	21 (68)	*0.087*		
Body height (cm)	50	160.9 ± 8.3	30	160.1 ± 10.0	*0.489*		
Body weight (kg)	50	65.9 ± 11.6	31	65.6 ± 11.5	*1*		
Number of chronic diseases	50	3.0 ± 1.7	31	3.8 ± 1.7	*0.343*		
Osteoarthritis	50	5 (10)	31	5 (16)	*0.415*		
Osteoporosis	50	4 (8)	31	6 (19)	*0.131*		
Diabetes	50	4 (8)	31	5 (16)	*0.258*		
Walking aid outdoors before fracture (%)	46	**16 (35)**	30	**23 (77)**	<***0.001***	**6.55 (2.05–20.96)**	**7.91 (2.20–28.51)**
Falling indoors, year before the fracture	49	**8 (16)**	31	**12 (39)**	***0.024***	**4.19 (1.32–13.32)**	**3.74 (1.04–13.51)**
Falling outdoors, year before the fracture	49	16 (33)	31	12 (39)	*0.580*		
C-statistic of the model							0.82
Hospital information							
Collum fracture, S72.0 (%)	50	31 (62)	31	21 (68)	*0.600*		
Type of surgery (%)	50		31		*0.338*		
Fixation		24 (48)		14 (45)			
Hemiarthroplasty		18 (36)		15 (48)			
Total hip replacement		8 (16)		2 (6)			
Lowest haemoglobin after surgery (g/L)	48	98.8 ± 12.6	29	96.0 ± 14.7	*0.356*		
Time from fracture to surgery (days)	50	3.1 ± 5.3	31	2.1 ± 1.9	*0.821*		
Information at discharge							
Difficulties in walking at the ward (%)	44	3 (7)	30	2 (7)	*0.980*		
Offending pain at discharge (%)	43	**12 (28)**	28	**17 (61)**	***0.006***	**5.97 (1.89–18.89)**	**5.66 (1.70–18.82)**
Duration of inpatient period (days)	50	**18 ± 12**	31	**29 ± 18**	***0.006***	**1.05 (1.01–1.09)**	**1.04 (1.00–1.09)**
C-statistic of the model							0.79
Information 6 weeks after the discharge							
Prescribed pain medication	50	27 (54)	31	23 (74)	*0.069*		
Lower body pain (VAS)[d]	50	**69.9 ± 77.9**	30	**169.8 ± 148.2**	***0.002***	**1.09 (1.04–1.15)**[g]	**1.10 (1.03–1.17)**[g]
Functional balance (score)[c]	48	**45.3 ± 6.2**	30	**36.9 ± 11.5**	***0.002***	**0.89 (0.82–0.96)**	0.93 (0.85–1.02)
Knee extension force, nonfractured side (N)	49	**249.6 ± 91.2**	29	**208.2 ± 77.8**	***0.029***[a]	**0.92 (0.85–0.98)**[g]	0.93 (0.84–1.02)[g]

Table 1: Continued.

	Trajectory					Binary logistic regression	
	No-to-minor-difficulty n = 50		Catastrophic n = 31		P value	Model I[e]	Model II[f]
	n		n			OR (95% CI)	OR (95% CI)
Knee extension force, fractured side (N)	46	187.5 ± 73.2	28	157.2 ± 67.9	*0.059*[a]		
Handgrip force (N)	49	205.7 ± 84.2	30	183.2 ± 79.2	*0.359*		
Time in home-dwelling (days)	50	41.3 ± 13.3	31	43.3 ± 33.1	*0.067*		
C-statistic of the model							0.86

[a] P value is adjusted with the body weight using marginal means.
[b] ADL: activities of daily living.
[c] BBS: range 0–56.
[d] VAS: range 0–600.
[e] Model I: OR for prediction in logistic regression for statistically significant variables adjusted for age and gender.
[f] Model II: OR for prediction in logistic regression for all statistically significant variables from Model I in one time point, adjusted for age and gender.
[g] VAS and knee extension force were divided by 10 for the regression analysis.
Statistically significantly different values between the study groups are bolded and P values are in italic.

older, had more indoor falls prior to the fracture, and were more likely to have osteoarthritis in the lower extremity and to use walking aids than those in the No-to-minor-difficulty trajectory. The results revealed that the risks for ending up in the Catastrophic trajectory were 6 to 8 times higher, if the participant used walking aid outdoors and about four times higher, if the participant had fell indoors in the previous year before the hip fracture. A recent study by Gill et al. [33] also found out that the change in functional status before an injurious fall was associated with functional recovery trajectories a year after the fall. Contrary to our results previous studies have suggested that factors related to the clinical condition of the patient, gender, or treatment of the fracture may predict poor recovery after a hip fracture [1, 29, 30, 32, 34–38]. In this study, only the duration of inpatient care was significantly longer among the Catastrophic than No-to-minor-difficulty group. A longer inpatient period may reflect poor health status or complications during the acute treatment of the fracture. However, we did not find differences between the groups in either the burden of chronic diseases or postoperative haemoglobin concentration.

Earlier studies have shown that older people suffer from persistent muscle weakness [39], balance impairment [40], and pain [41] after hip fracture. It is well known that these factors are associated with walking limitation and disability among older populations. The participants in the Catastrophic group had poorer postural balance, knee extension force, and more pain than those in the No-to-minor-difficulty group. Pain in the low back, hip, and knee regions was particularly high in the Catastrophic group. They also experienced offending pain in the lower body and the risk for ending up in the Catastrophic trajectory in walking outdoors was almost six times greater, if the participant experienced offending pain on the fractured limb at discharge. Severe pain often leads to physical inactivity [41], restriction of painful movements, and fear of pain, all of which may induce even more pain and further avoidance of activity. The coexistence of walking disability, pain, poor balance, and muscle weakness predicts loss of independence in the near future [2, 42, 43].

At discharge, participants of this study received a written home exercise program, which is part of the standard care. However, recovery of walking or compliance to the program was not systematically followed up [6]. Rehabilitation after hip fracture is important and should be extended to home after discharge. Currently, there are no accurate rehabilitation guidelines for walking recovery after hip fracture.

We investigated perceived difficulties in walking outdoors among 81 consecutive community-dwelling over 60-year-old hip fracture patients. Those who were too frail to travel to the laboratory assessments and who had severe memory problems or depression were excluded from the study. Therefore, our sample is not thoroughly representative among all hip fracture patients. Participants were followed up during the critical time for recovery, on average two months after fracture and six weeks after discharge. Perceived difficulty in walking outdoors before the fracture was assessed at the hospital. We believe, however, that our participants were able to recall their before fracture condition as this was assessed within the first ten days after fracture.

In clinical populations, the recruitment of participants is challenging, especially in studies where frequent travelling is required or where long-term interventions are incorporated into the study design. In the present study, the number of participants was based on sample size calculations of the RCT design with mobility recovery as the main outcome [6]. Therefore, it might be that the present secondary analysis is underpowered to detect all predictors of walking recovery. Owing to sample size, we modelled two trajectories for early outdoor walking recovery, which fitted the data well. With a larger sample size more than two trajectories might have been found. However, we believe that with this data we have identified the most important paths characterising early walking limitation after hip fracture and the key determinants defining outdoor walking recovery. Our main outcomes were perceived difficulty in walking outdoors and walking

Table 2: Characteristics of participants by walking trajectories in walking 500 meters (n, mean ± SD, median P value/n (%), χ^2 P value) and binary logistic regression model for statistically significant variables as a predictor for catastrophic trajectory.

	Trajectory					Binary logistic regression	
	No-to-minor-difficulty n = 27		Catastrophic n = 54		P value	Model I[e]	Model II[f]
	n		n			OR (95% CI)	OR (95% CI)
Demographic and prefracture information							
Age	27	**77.9 ± 6.4**	54	**81.0 ± 7.3**	***0.035***		
Women (%)	27	23 (85)	54	40 (74)	*0.257*		
Body height (cm)	27	160.9 ± 8.1	53	160.4 ± 9.4	*1*		
Body weight (kg)	27	64.9 ± 10.1	54	66.3 ± 12.3	*0.485*		
Number of chronic diseases	27	3.1 ± 1.8	54	3.5 ± 1.7	*0.634*		
Osteoarthritis	27	**0 (0)**	54	**10 (19)**	***0.017***[h]		
Osteoporosis	27	2 (7)	54	8 (15)	*0.339*		
Diabetes	27	1 (4)	54	8 (15)	*0.134*		
Walking aid outdoors before fracture (%)	25	**6 (24)**	51	**33 (65)**	<***0.001***	**5.77 (1.83–18.20)**	**5.49 (1.70–17.77)**
Falling indoors, year before the fracture	27	**3 (11)**	53	**17 (32)**	***0.041***	**4.49 (1.11–18.10)**	**4.64 (1.01–21.36)**
Falling outdoors, year before the fracture	27	8 (39)	53	20 (38)	*0.472*		
C-statistic of the model							0.79
Hospital information							
Collum fracture, S72.0 (%)	27	20 (74)	54	32 (59)	*0.190*		
Type of surgery (%)	27		54		*0.454*		
Fixation		11 (41)		27 (50)			
Hemiarthroplasty		11 (41)		22 (41)			
Total hip replacement		5 (18)		5 (9)			
Lowest haemoglobin after surgery (g/L)	26	99.7 ± 14.7	51	96.7 ± 12.7	*1*		
Time from fracture to surgery (days)	27	2.2 ± 1.9	54	3.0 ± 5.1	*0.347*		
Information at discharge							
Difficulties in walking at the ward (%)	25	2 (8)	49	3 (6)	*0.761*		
Offending pain at discharge (%)	25	7 (28)	46	22 (48)	*0.105*		
Duration of inpatient period (days)	27	**17 ± 13**	54	**26 ± 16**	<***0.001***	**1.05 (1.00–1.10)**	**1.05 (1.00–1.10)**
Information 6 weeks after the discharge[j]							0.70
Prescribed pain medication	27	15 (56)	54	35 (65)	*0.419*		
Lower body pain (VAS)[d]	27	**54.9 ± 74.4**	53	**134.1 ± 129.0**	***0.004***	**1.09 (1.02–1.16)**[g]	**1.07 (1.00–1.15)**[g]
Functional balance (score)[c]	26	**46.8 ± 4.7**	52	**39.8 ± 10.4**	***0.004***	**0.86 (0.77–0.96)**	0.90 (0.81–1.01)
Knee extension force, nonfractured side (N)	27	252.9 ± 85.4	51	224.3 ± 89.0	*0.056*[a]		

Table 2: Continued.

	Trajectory					Binary logistic regression	
	No-to-minor-difficulty $n = 27$		Catastrophic $n = 54$		P value	Model I[e]	Model II[f]
	n		n			OR (95% CI)	OR (95% CI)
Knee extension force, fractured side (N)	26	191.0 ± 66.7	48	167.9 ± 74.6	*0.087*[a]		
Handgrip force (N)	20	210.0 ± 73.3	42	190.5 ± 86.9	*0.155*		
Time in home-dwelling (days)	27	42.2 ± 12.7	54	41.9 ± 26.6	*0.235*		
C-statistic of the model							0.79

[a] P value is adjusted with the body weight using marginal means.
[b] ADL: activities of daily living.
[c] BBS: range 0–56.
[d] VAS: range 0–600.
[e] Model I: OR for prediction in logistic regression for statistically significant variables adjusted for age and gender.
[f] Model II: OR for prediction in logistic regression for all statistically significant variables from Model I in one time point, adjusted for age and gender.
[g] VAS and knee extension force were divided by 10 for the regression analysis.
[h] Logistic regression analysis impossible due to quasicomplete separation and because maximum likelihood parameter does not exist.
Statistically significantly different values between the study groups are bolded and P values are in italic.

500 meters, which reflects the individual's own understanding of her or his ability to cope with her or his own environment. This perspective, which has been more rarely investigated [3], is important, when defining the independence and capacity of the older people recovering from a hip fracture to participate in the community.

5. Conclusions

The determinants of severe disability in outdoor walking need to be acknowledged in clinical practice in order to design effective and individualized rehabilitation strategies and to prevent disability and institutionalization. These factors are easy to assess in clinical practice and some are modifiable by targeted rehabilitation. Older hip fracture patients with poor prognosis for outdoor walking recovery need special attention, systematic physical rehabilitation, and pain management to promote their participation and independent living in the community.

Conflict of Interests

The authors are independent of the funders and have no conflict of interests in this study.

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V

EFFECTS OF MULTI-COMPONENT HOME-BASED PHYSICAL REHABILITATION PROGRAM ON MOBILITY RECOVERY AFTER HIP FRACTURE: A RANDOMIZED CONTROLLED TRIAL

by

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