RECOVERY OF PHYSICAL FUNCTIONING

AFTER TOTAL HIP ARTHROPLASTY

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Doctoral thesis

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TABLE OF CONTENTS

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Oslo, August 2013.

Kristi Elisabeth Heiberg.

SUMMARY

Purpose. The overall aim of this thesis was to examine recovery of physical functioning in patients with hip osteoarthritis (OA) during the first year after total hip arthroplasty (THA). The specific aims were 1) to examine the desires of a group of patients regarding improvements in physical functioning before they underwent THA and at three and 12 months after surgery, 2) to examine changes in physical functioning during the first year of recovery and examine which preoperative measures predicted outcomes in walking distance at 3 and 12 months after surgery, and 3) to examine the immediate and long-term effect of a walking skill training program performed between three and five months after surgery on physical functioning.

Materials and Methods. This study had a prospective, longitudinal design. Patients with hip OA scheduled for primary THA were consecutively recruited from two hospitals the day they were hospitalized for surgery (Paper I-III). One hundred and three patients were included in the study. Assessments were performed four times; before surgery, and at three, five, and 12 months after surgery. At three months, 68 patients were randomly allocated to a training group (n = 35) or a control group (n = 32) without supervised physiotherapy (Paper III). The walking skill training program comprised two sessions a week for a total of 12 sessions. It consisted of functional exercises and activities in a weight-bearing position aimed to improve walking, muscle strength, flexibility, balance and endurance. There were continuous supervision and feedback from a physiotherapist during the training sessions.

Both performance-based and self-reported measures were applied. The performance-based measures in Papers II and III were the 6-minute walk test (6MWT), which was the primary outcome measure in Papers II and III, the stair climbing test (SCT), the figure-of-eight test, the Index of Muscle Function (IMF), and the active hip range of motion (ROM). Self-reported outcome measures were a modified version of the Patient Specific Functional Scale (PSFS) in Paper I, the Harris Hip Score (HHS) and the Hip Dysfunction and Osteoarthritis Outcome Score (HOOS) in Papers II and III, and the self-efficacy for physical activity in Paper III.

The free-text responses from the PSFS were coded according to the International Classification of Functioning, Disability and Health (ICF) to the 1st, 2nd, and 3rd category levels (Paper I). Group differences were analyzed by student sample *t*-tests (Paper II and III). Differences over time within groups were examined by Friedman's test (Paper I), one-way repeated measures analysis of variance (ANOVA) (Paper II), and differences in changes over time between groups with adjustment for sex and pretest scores were examined by analysis of covariance (ANCOVA) (Paper III). Relationships were analyzed by bivariate and multivariate regression analyses (Paper II).

Results. Eighty-eight percent of the desires of improvements in physical functioning reported by the patients were classified into the Activities and Participation component of the ICF, while 12 % were classified into Body Functions and Structures. The categories of Walking (d450), Moving around (d455) and Recreation and leisure (d920) included about half of the responses at all the assessment times. At three months after surgery, there were fewer responses classified into the Recreation and leisure category, while more responses were classified into the category of Dressing (d540). The number of functional improvement desires decreased during the first postoperative year ($P < 0.001$) (Paper I).

In performance-based measures of physical functioning, small improvements were found from preoperative to three months postoperatively in 6MWT ($P < 0.01$) and SCT ($P < 0.05$) scores, while all measures of physical functioning had improved from three to 12 months postoperatively ($P \leq .001$). In contrast, all the self-reported measures showed substantial improvements at three months with small further improvements at 12 months ($P < 0.001$). Older age, being a woman, impaired preoperative 6MWT distance and hip ROM predicted a worse outcome in 6MWT at three and 12 months ($P \leq 0.01$) (Paper II).

The training group had larger improvements than the control group immediately after the intervention on 6MWT with an adjusted mean group difference of 52 meters (95% CI 29, 74; $P < 0.001$) and on the SCT of -1 (-2, 0) second ($P = 0.01$). There were also differences between the groups in the figure-of-eight test ($P = 0.02$), IMF ($P = 0.001$), active hip ROM in extension ($P = 0.02$), HHS ($P = 0.05$), and self-efficacy ($P = 0.04$). On the 6MWT the difference between the groups persisted at 12 months after surgery with an adjusted mean group difference of 52 (24, 80) meters ($P < 0.001$) and on the SCT of -1 (-3, 0) seconds ($P = 0.05$) (Paper III).

Conclusions. The patients wanted to improve the ability to walk long distances and to participate in usual recreation and leisure activities. Their physical functioning improved during the first year after THA, and those with poor preoperative walking distance gained the most from surgery. Age, sex and preoperative walking capacity and hip flexibility predicted postoperative walking capacity. The walking skill training intervention was effective in improving walking capacity and no adverse events were registered. The effect still sustained one year after surgery.

Key words: Arthroplasty, replacement, hip; Recovery of function; Walking; Rehabilitation; desires; functional improvement; ICF

LIST OF PAPERS

Paper I — Heiberg KE, Ekeland A, Mengshoel AM. Functional improvements desired by patients before and in the first year after total hip arthroplasty. *BMC Musculoskelet Disord 2013;14(1):243*

Paper II — Heiberg KE, Ekeland A, Bruun-Olsen V, Mengshoel AM. Recovery and prediction of physical functioning outcomes during the first year after total hip arthroplasty. *Arch Phys Med Rehabil. 2013;94(7):1352-9.*

Paper III — Heiberg KE, Bruun-Olsen V, Ekeland A, Mengshoel AM. Effect of a walking skill training program in patients who have undergone total hip arthroplasty: Followup one year after surgery. *Arthritis Care Res (Hoboken). 2012;64(3):415-23.*

ABBREVIATIONS

6MWT	Six-minute walk test
ADL	Activity of daily living
BMI	Body mass index (kg/m^2)
CI	Confidence interval
Fig. 8	Figure-of-eight
HHS	Harris hip score
HOOS	Hip dysfunction and osteoarthritis outcome score
ICF	International Classification of Functioning, Disability and Health
IMF	Index of muscle function
ITT	Intention-to-treat
OA	Osteoarthritis
OARSI	Osteoarthritis Research Society International
QOL	Quality of life
RCT	Randomized controlled trial
ROM	Range of motion
SF-36	Medical Outcomes Study Short-Form Health Survey
SCT / ST	Stair climbing test
THA	Total hip arthroplasty
TKA	Total knee arthroplasty
TUG	Timed "Up & Go" Test
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index

1 BACKGROUND

During my professional life as a physiotherapist, I have mainly worked with hospitalized patients with orthopaedic and rheumatic disorders. Patients treated with total hip- and knee arthroplasty for osteoarthritis (OA) have been of particular interest to me.

The number of patients with total hip arthroplasty (THA) is increasing yearly in Norway. Traditionally, these patients receive physiotherapy while they are in hospital, and most of them continue to receive physiotherapy the first months after surgery in order to optimize their physical functioning. From my experience, when the patients were asked by the surgeons, they often said that they were satisfied with obtained pain relief and physical functioning after surgery. In many cases, however, I observed limitations in physical functioning that were also confirmed by the patients several months and maybe years after surgery. These experiences inspired me to investigate the recovery of physical functioning during the first year after surgery and the effects of a walking skill training program on recovery outcomes.

Thus, the overarching aim of this thesis was to examine the recovery of physical functioning in patients with hip OA during the first year after THA. In the introduction the OA disease and development of impaired physical functioning will be presented, followed by THA and recovery of physical functioning after surgery, measurements to assess physical functioning, and the literature on effects of exercise after THA.

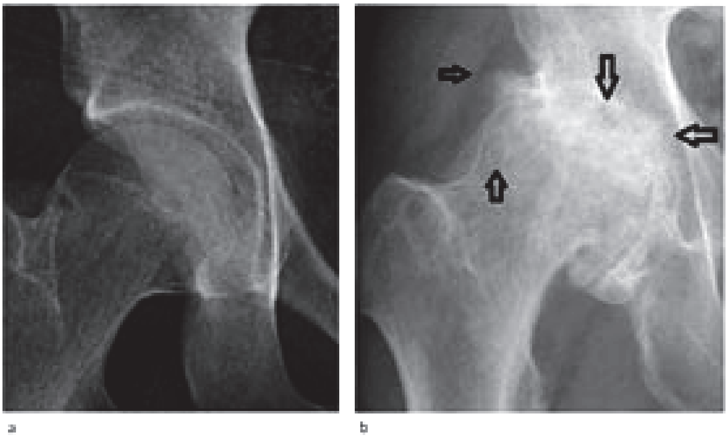
2 INTRODUCTION

2.1 Osteoarthritis

2.1.1 Prevalence, pathogenesis, risk factors and diagnosis

All patients included in this thesis had THA surgery because of severe OA in the hip. OA is probably the most prevalent chronic joint disease, with the hip, knee and hand as the most frequently affected joints.[1] By the age of 80 years nearly everyone has OA in one or more joints.[2] In people above 50 years the prevalence of symptomatic OA in hips and knees has been estimated to be approximately 7-11%.[3;4] In Norway a prevalence of 5.5 % for hip OA was found in an age group of 24 to76 years.[5]

Characteristic for OA is the degenerative process that involves the synovial joints,[5;6] accompanied by progressive changes in the form of cartilage loss, sclerotic changes in subchondral bone tissue, and development of osteophytes and cysts [6;7] (Figure 1). Soft-tissue structures can also be affected by synovial tissue proliferation, thickening of the joint capsule, laxity of ligaments and weakness in muscles around the joint.[2;7;8]



From Flugsrud et al. Tidsskr Nor Legeforen 2010; 130: 2136-40

Figure 1. Radiographs of normal hip joint (left) and hip osteoarthritis (right) with osteophyte formation ↔, cysts ↑, subchondral sclerosis ←, and narrowing of the joint space ↓.

In general, increased age is a risk factor, and more women than men get OA.[2;7;9;10] Genetic factors account for at least 50 % of cases of OA in the hip.[7] Additionally, obesity, mechanical factors, joint deformity, D-vitamin status, smoking, less than 12 years of education, unemployment, and intensive physical activity at work have been identified as risk factors for developing OA of the hip.[5;9;11] While OA is believed to be related to the degree of wear and tear of the cartilage and surrounding tissues, participation in leisure activities does not seem to be a risk factor.[12]

There are several ways of diagnosing OA, based on radiographic or pathological findings (as well as the opinion of a physician or specialist).[13] In this thesis the international clinical criteria published by the American College of Rheumatology[14] were used by the orthopaedic surgeons to diagnose the condition (Table 1). According to these criteria, a patient can be diagnosed with hip OA if hip pain for most days of the prior month is present, combined with radiographic criteria such as osteophytes and/or joint space narrowing, and/or erythrocyte sedimentation rate (ERS) ≤ 20 mm/hour.

Table 1. The American College of Rheumatology criteria for the classification of hip osteoarthritis.[14]

Criteria of hip OA	OA is present if the items present are
Clinical and radiographic 1. Hip pain for most days of the prior month. 2. ERS ≤ 20 mm/h (laboratory) 3. Radiograph femoral and/or acetabular osteophytes 4. Radiographic hip joint space narrowing	1, 2, 3 or 1, 2, 4 or 1, 3, 4

2.1.2 Symptoms, signs and consequences for physical functioning

The cardinal symptoms of hip OA are joint stiffness and pain. Stiffness worsens at rest and is relieved by movement, while pain is evoked by loading the affected hip joint over time. In turn this may limit the ability to walk.[7;15] At an early stage of OA, hip pain is most prevalent after large amount of weight-bearing activity, but at an advanced stage the patients typically describe the pain as prevalent in most weight-bearing activities, and the pain may also occur at rest and disturb sleep.[15] No correlation has been found between radiographic changes of the hip joint and clinical severity.[16]

Common signs of OA are joint swelling, deformity of the joint, decreased muscle strength in hip and thigh muscles, and limited hip range of motion (ROM) in internal rotation, abduction and extension.[2;7;8;15;17-19] In order to avoid pain, the patients try to unload the affected hip, and a limping gait is often observed. This limping may worsen when patients become unable to extend the hip during walking. Use of walking aids in order to reduce the weight load of the hip joint and thereby enable walking ability, may be an option for the patient. However, unloading the affected hip during walking may in turn lead to muscle weakness, and the inability to walk long distances may reduce a person's aerobic capacity.[2;17]

These different signs and symptoms lead to functional limitations to such a degree that OA has been said to be the most common cause of disability in older people.[20] Limitations in walking leads to reduced ability to perform daily activities and participate in sports, leisure- and social activities, and many patients experience dependency on others and inability to work.[7] More specifically, typical problems experienced by the patients are related to executing different tasks, such as picking up items from the floor, climbing stairs, and go for walks at their usual speed and distance.[2;17;21;22]

2.1.3 Conservative treatment of hip OA

There is no known specific cure for OA, and therefore treatments are aimed at reducing pain and activity limitations.[6] A combination of pharmacological and non-pharmacological treatments is often required.[23]

Pharmacological treatment for pain consists mainly of analgesics, such as paracetamol. If paracetamol is not sufficiently effective non-steroidal anti-inflammatory drugs (NSAIDs) are offered.[23;24] Among the options are also intra-articular injections with corticosteroids.[23]

Additionally, non-pharmacological treatments such as transcutaneous electric nerve stimulation (TENS) and acupuncture may also reveal pain.[23]

Education programs and exercise interventions are usually initiated in addition to the pharmacological treatment. The education programs focus on pain management, weight control, and joint protection, including advice about the importance of staying physically active.[1;23;25] Such programs have been found effective in reducing pain and activity limitations.[25]

In order to reduce pain and activity limitations there is evidence that effective exercise programs are those including muscle strengthening exercises, flexibility exercises, and exercises to improve aerobic capacity.[23-30] Water exercise is also effective.[23;31] Success of exercise therapy depends on the patient's adherence to the exercise program, and an individualized approach to exercise prescriptions is required.[30] Generally, different kinds of treatment have shown some effect in reducing pain and activity limitations in patients with hip OA. For the majority of the patients, pain and functional status seem to deteriorate slowly over years.[32] However, for some patients with OA, adequate pain relief and functional improvements are not obtained from pharmacological and non-pharmacological treatments, and these patients are considered for treatment by total hip arthroplasty surgery.[23;29] This was the case for the patients included in the present study.

2.2 Total hip arthroplasty

2.2.1 History of hip arthroplasty

Over 100 years of operative history has taken place since the first hip replacement attempt was performed in Germany in 1891.[33] In the first attempts, the femoral head was replaced with a new head made of ivory for patients whose hip joints had been destroyed by tuberculosis. Later, surgeons experimented by placing various tissues, such as the fascia lata, skin, or pig bladders submucosa, between the articulating hip surfaces.[33;34] In 1925, Smith-Petersen created a hollow hemisphere of glass to be placed over the femoral head, but the glass failed to withstand the great forces going through the hip joint, and it shattered.[33] The glass was later replaced by stainless steel. Smith-Petersen also introduced a Vitallium mould arthroplasty that was widely used for patients with hip OA. An “ultra-long” cup survival up to 62 years has been reported.[35]

In 1938, Wiles developed the first prosthetic total hip replacement.[36] The arthritic hip joint was replaced by an artificial joint made of stainless steel. This new joint was fitted to bone with bolts and screws. There were, however, problems with poor design, inferior materials and mechanical failure of the arthroplasty.[34] In the 1950’s, a cemented femoral stem and a cobalt-chrome socket as the new acetabulum, was developed. This prosthesis had a good survival rate, but release of metal particles and thereby local effects on surrounding tissues made it unpopular.[33] In the early 1960s, the orthopaedic surgeon Sir John Charnley designed a low friction arthroplasty, consisting of three parts; a metal femoral stem with a small femoral head, a polyethylene acetabular component, and acrylic bone cement.[34] His important contribution to the development of total hip replacement was the idea of low friction, the use of acrylic cement, and the introduction of polyethylene as the bearing material. In retrospect, it can be said that this prosthesis designed by Charnley has revolutionised the management of the arthritic hip.[33;34] However, failure mechanisms of these early total hip replacements included fracture of the implant, asepetic loosening, infection and dislocation, and continuous developments have thereafter been performed to reduce the rate of failure.[34] The cemented prostheses used today, including the Exeter and the Spectron prostheses used in this study, are principally almost identical to the Charnley prosthesis (Figure 2).

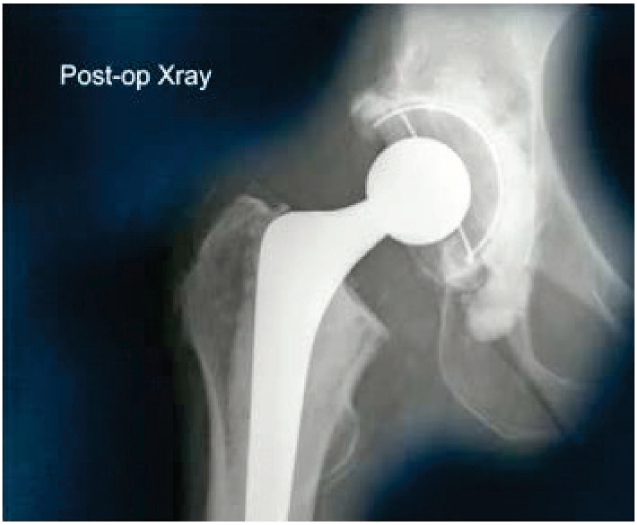
 

Figure 2. Exeter hip prosthesis (left). Postoperative radiograph of Exeter hip prosthesis (right).

THA has become one of the most widely performed procedures in orthopaedic practice. In Norway, 7786 primary THAs were performed in 2012, and 68 % of those operated were women.[37] From 1995 to 2006, there were performed 70138 primary THA operations, and 79 % of the prostheses were cemented.[38] The 10-year survival rate of hip prosthesis in Norway today, comprising all age groups and prosthesis types, is at 93 %.[38] In the Swedish hip register, a seven to nine year survivorship of 98 % was reported for cemented Exeter and Spectron prostheses.[34] The THA procedure, which has been called "the orthopaedic operation of the century", seems to be hugely successful.[33;34]

In the years to come, an increase in the numbers of people undergoing THAs is anticipated because of an ageing population. With a better survival of the prosthesis and fewer postoperative complications, an increased number of younger individuals are also expected to get THA. It is likely that younger people will have higher expectations about what they should be able to do after undergoing THA than older people usually may have had. Thus, a better understanding about recovery of physical functioning and exercise to approach such expectations are important.

2.2.2 Physical functioning following THA

Physical functioning is a term related to move around and to "the ability to perform daily activities".[39] In 2001, the World Health Organization (WHO) published the latest version of the International Classification of Functioning, Disability and Health (ICF).[40] The model may help to understand the complexity of physical functioning due to OA and the recovery of physical functioning after THA. According to the model, the concept 'functioning' is a broad term that serves as an 'umbrella' term for the components Body Functions and Structures, and Activities and Participation[40] (Figure 3). ICF is aimed at describing functioning associated with health conditions.[41] The term Body Functions includes disease impacts of OA, such as pain, fatigue, decreased muscular strength and endurance, and examples of Body Structures are related to structural changes in the hip joint as a result of the disease, e.g. cartilage loss. The term Activities and Participation includes activity limitations related to the affected joints in the lower limbs, such as problems with walking, climbing stairs and dressing, while participation restrictions can be related to decreased participation in work, leisure and social activities. The model shows that the different terms are mutually dependent on each other (Figure 3).

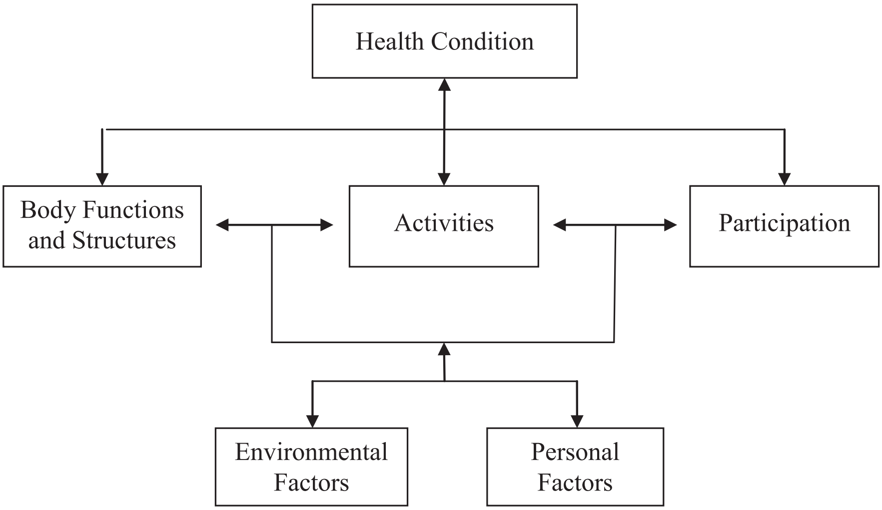


Figure 3. International Classification of Functioning, Disability and Health

The terms from ICF can be applied when physical functioning in patients with hip OA operated with THA is to be described and understood.[42] These patients' physical functioning is often associated with impairments of body functions (e.g. pain, muscle weakness, and restricted hip flexibility), changes in body structures (e.g. the new joint has damaged several proprioceptors because of capsular excision, and injured some muscles because of splitting or detaching them, followed by suturing and reattaching them), activity limitations (e.g. limited walking ability and problems with putting on socks and shoes), and participation restrictions (e.g. reduced participation in leisure activities and at work). Although the painful hip joint has been replaced by THA, many patients still carry with them the previous impairments in body function, e.g. reduced hip ROM and muscle weakness, activity limitations and participation restrictions from having OA for years. For example, a compensatory movement pattern may have become a habit after years of volitional unloading of the painful limb, and this problem may sustain after surgery.[43-45] However, if this habit of volitional unloading sustains, OA in other lower extremity joints, especially the contralateral knee, may occur from the asymmetric dynamic loading during walking.[43;46] Additionally, the changes in body structures that appeared from surgery may explain the picture of a further disturbance in the neuromuscular function. Therefore, altered weight-bearing and impaired balance and gait may still be present after surgery.[47] The topic of this thesis is recovery of physical functioning following THA, which was investigated as normalization of limitations in the ICF components Body Functions and Structures, Activities and Participation.

2.2.3 Measures to assess recovery of physical functioning after THA

Traditionally, the same measurements have been used to assess the patients' development of OA and their normalization of limitations (recovery) following THA surgery. However, there was no consensus as to which are the best outcome measures to assess recovery of physical functioning following THA when this study was started.[48;49] In the planning of the study it was decided to include both self-reported measures and performance-based measures that were well known and commonly applied in the field as they are recognized to capture different aspects of physical functioning.[39;50;51] We also wanted to be able to compare our results to previous research. The measurements should evaluate the different aspects of physical functioning that were trained by the intervention and capture the various components of physical functioning that are outlined in the ICF model.

The self-reported condition-specific instruments Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Harris Hip Score (HHS), in addition to pain scale measurements are among the most frequently used instruments after THA.[52;53] The Hip dysfunction and Osteoarthritis Outcome Score (HOOS) that is an extension of the WOMAC was included in this thesis.[54] The items of the HOOS are in regards to the patients' symptoms, stiffness, and pain, as well as ability to perform common daily activities, sport and quality of life. Creaking sounds from the joint, morning stiffness, pain at different occasions, rising up from a chair, getting dressed, getting in or out of a car, ascending and descending stairs, walking on flat or uneven ground, running, or the quality of life related to the hip dysfunction are examples of topics examined in the HOOS questionnaire.[54] The HHS include questions about pain, physical functioning, such as walking on stairs, ability to use public transport, sitting, dressing, limping, the use of a supporting device while walking, walking distance, and deformity.[55] HOOS and HHS include items of pain and stiffness at the Body Functions and

Structures component as well as items of physical functioning at the Activities and Participation component of the ICF.

To gain a broader picture of the patients' recovery, several performance-based measures of physical functioning are also frequently used after THA. These tests assess the patients' actual observed performance.[48;50] Usual performance-based outcome measures assess the patients' physical capacities, such as walking capacity by the six-minute walk test (6MWT) and stair climbing test (SCT).[53] Additionally, measures of muscle strength by e.g. leg press or Cybex machine, and hip ROM by a goniometer, are often used to assess outcomes of physical functioning. In this thesis 6MWT, SCT, figure-of-eight test, Index of muscle function (IMF) and hip ROM were included to assess physical functioning at the Body Functions and Structures component of the ICF. In 2013 the Osteoarthritis Research Society International (OARSI) published a consensus report recommending performance-based tests to assess physical functioning in people with hip and knee OA,[56] and the 6MWT and SCT were among the tests recommended. The Timed "Up & Go" Test (TUG) and 30-second chair-stand test were also recommended, but these tests were not included in this thesis.[56]

When planning this study my colleagues and I considered it appropriate to also investigate what the patients themselves actually stated they wanted to improve. This was in accordance with an important tenet in rehabilitation ideology proposing that the patients should be considered as experts in their own lives.[57] The usual questionnaires do not necessarily fully cover what functional improvements the patients actually hope to achieve following THA. The Patient-Specific Functional Scale (PSFS) was therefore included, as it is developed to identify the kinds of physical functioning the patients report to be essential.[58-60] In the PSFS the patients describe in free text what they consider to be a problem, instead of responding to prestated answer alternatives. The PSFS has previously been reported used in patients with knee dysfunction,[59] neck dysfunction,[61] and low back pain,[58] but to my knowledge, not in patients with THA.

2.3 Recovery of physical functioning following THA

The goal of THA surgery is to relieve pain and thereby enable the patient to perform weight-bearing activities. After surgery a natural healing process of the body tissues occurs and the patients gradually regain ability to perform daily activities.[62] An overview of the knowledge of course and outcome of physical functioning, prediction of physical functioning as well as evidence for the effect of exercise to improve recovery as it appeared when this study was planned, are presented in the following.

2.3.1 Course and outcome of physical functioning

To obtain pain relief is one of the main reasons for the patients to get THA.[63] Prior research have shown that the patients experience considerable and early pain relief.[64-66] Pain has been found to be reduced by approximately 60-70 % at three months after surgery when compared to preoperatively,[64;66] and after one year it still remains at this low level.[66] It seems that early and substantial pain relief that lasts for several years is likely after THA.[67-69] Thus, pain is not likely to restrict patients from being physically active anymore, and the patients are supposed to regain ability to do routine daily activities, e.g. climbing stairs and going shopping.[70]

Studies applying self-reported measures have shown that patients consider their ability to perform daily usual activities, such as changing position in bed, sitting, climbing stairs, and walking on even ground, to be at the same level as before surgery as early as two weeks after surgery.[48] At three months after surgery, scores of physical functioning had improved by approximately 50 % in WOMAC and HOOS compared to preoperative measures,[64;71;72] and at six and 12 months they had approached the best possible score.[64;72-75] The recovery course in self-reported physical functioning seemed to show a pattern of early improvements with small further changes after six months.

With regard to performance-based measures, walking ability has been assessed in most of the prior studies. Gait adaptations are known to persist after THA surgery,[76] and gait analysis have revealed that asymmetric gait is still present at six[77] and 12[78] months. Walking distance measured by the 6MWT has been reported to increase by 70 meters to149 meters after one year compared to preoperative measures.[73;79] Patients' score on 6MWT deteriorate the first postoperative weeks, improve slightly at three months, and further gradually increase to 12 months postoperatively.[50;71;73;80] However, contradicting results have also been reported, as a faster recovery with large improvement in 6MWT has been reported to occur already at three months with a mean change from preoperative measures of approximately 60 meters in one study[81] and 100 meters in another study[79] and with small further improvement of 40 meters at six months.[79] Therefore, the course of recovery and magnitude of improvements to be expected in 6MWT is uncertain. This uncertainty and different course of recovery assessed by performance-based and self-reported measures inspired me to further investigate the first year recovery in a sample of Norwegian patients after THA.

The literature showed that the outcomes in physical functioning and pain improve during the first year when compared to preoperative measures, and the recovery patterns are generally positive after THA. However, it also showed that many patients with THA continue to have functional limitations several months and years after surgery.[82] The operated hip is reported to remain weaker than the unaffected hip[83-87] and weaker than in healthy older adults[88] several months after surgery. The abductor and hip flexor musculature had decreased muscle strength, and persisting muscle atrophy was also observed in the same muscles.[89] Additionally, the patients walked more slowly than healthy older adults for several months and even years after surgery.[78;86;90;91]

When the patients' physical functioning was compared to healthy peers at the same age in a systematic literature review it was shown that the patients' outcome scores in self-reported physical functioning had improved from approximately 50 % at preoperative to approximately 80 % to that of healthy peers 6-8 months after THA surgery.[90] The patients' capacity in walking and actual level of daily activity was of 70 % of healthy peers at preoperative and recovered to approximately 80 % after surgery.

These findings of comparisons to the patients' healthy hip and age-matched controls may be a bit disappointing. Although today's implants have been designed to tolerate vigorous activities,[82] it seems that the patients continue to have a lower level of physical functioning after THA than their healthy peers. This may be related to limitations in the prosthesis, to the recommendations regarding physical activity given by health professionals, or it may be related to the physiotherapy given to the patients. The physiotherapy may not have been appropriate to optimize the patients’ physical functioning. Thus, in addition to further investigate the patients’ course of recovery it appears to be a need to develop a new exercise program and examine its effects.

2.3.2 Prediction of physical functioning after THA

Another relevant question that may be a topic for further investigation is whether there are any factors that can predict the patients’ recovery of physical functioning, especially walking, after THA. It might be useful for the clinicians before surgery to identify patients at risk of a poor outcome in physical functioning after surgery. Prior research has found that factors such as age, sex, body mass index (BMI), comorbidities, expectations, and preoperative self-reported physical functioning can predict the outcome in self-reported physical functioning after THA.[92-97] One study reported that patients with a score on the preoperative performance-based measure TUG test of less than 10 seconds were likely to be able to walk without an assistive device at six months after surgery.[98] This information seemed to be of limited relevance for Norwegian patients, as they, from my experience, in general are in no need of assistive devices six months after surgery. Instead of investigating the use of a walking device it was considered beneficial to investigate a walking capacity measure. Prediction of walking after THA could give the patients realistic expectations, motivate them for training, and influence the training programs. Hence, it could be advantageous to identify predictors of the specific performance-based outcome of 6MWT after THA.

2.3.3 Physiotherapy after THA

Physiotherapy is an important part of the patients’ rehabilitation after THA. In order to exceed the natural recovery course and achieve the best possible outcomes in physical functioning, most patients seek assistance from a physiotherapist after surgery.[99] The main goals of physiotherapy are to optimize the recovery of physical functioning and avoid persistence of impairments, such as muscle weakness and limitations in flexibility and cardiovascular capacity.[100;101] Traditionally, different kinds of exercises are initiated in trying to reach these goals.

Physiotherapy during hospital stay

At Norwegian hospitals the patients usually meet a physiotherapist the first day after THA surgery. The daily physiotherapy session comprises active exercises in bed aimed to prevent thrombosis, joint stiffening, facilitate tissue healing and muscle activation, and to start walking with a supporting device.[82;102-104] Further, the patients are instructed and encouraged to continue to do these exercises at home after discharge, as well as go for walks. All patients studied in this thesis attended to this practice when they were hospitalized. Few randomized controlled trials (RCTs) investigating the effect of physiotherapy in the early postoperative phase at the hospital have been performed before this study started. Two studies investigated the effect of bed exercises. In one study bed exercises was investigated as an addition to mobilization[105] and in another as an addition to a gait re-education program.[106] No immediate or followup effect was found on pain, hip ROM, or the ability to move from supine to sitting, sitting to standing, walking, or stair climbing.[105-107] This finding of no additional effect from bed exercises on physical functioning may seem disappointing as it is a usual procedure to perform bed exercises while at hospital.

Physiotherapy after discharge from hospital

Physiotherapy after discharge from hospital usually takes place in a variety of inpatient, outpatient, and community settings, mainly within the first three months after surgery.[104;108;109] In Norway, some of the patients are sent directly from the hospital to rehabilitation centres, but most of them return directly home and go to outpatient physiotherapy immediately after discharge, or after some weeks.[68;104] The patients in this thesis also adhered to this practice.

There are no evidence-based clinical guidelines with recommendations or consensus on what kind of physiotherapy that should be given after discharge.[104] It seems that the exercise programs mainly consist of muscle strengthening exercises with little weight, stretching exercises, balance, transfer-, and walking aid practice, and the usual recommendations are to return to low-impact activities and avoid high-impact activities.[104;108]

Although there is a longstanding tradition for patients to attend physiotherapy after discharge, quite a few studies examining the effect of physiotherapy exercise have been performed. Ten RCTs examining different kind of exercises were identified and found in full-text before 2009 when the present study was planned.

In six studies the exercise programs were performed in the period from immediately after hospital discharge and in the first three postoperative months (Table 2). Some of them examined different exercise interventions in addition to the standard rehabilitation programs, such as treadmill training,[110] progressive resistant training,[111] and arm interval training.[112] These interventions were effective on self-reported physical functioning,[110;112] hip ROM, muscle strength,[110;111] gait symmetry,[110], walking,[112] and cardio respiratory capacity.[112] In some studies inpatient rehabilitation with supervision was compared to home-based exercise without supervision, but no additional effects were found from supervised exercise.[113;114] Another study compared different starting time points and found no significant between-group differences.[115]

Four exercise studies were performed with starting time point after three months postoperatively (Table 3). Interventions of aerobic dance in one study[116] and home-based exercises together with daily walks in another,[117] both of them compared to no training, showed improvements in either cardio respiratory capacity,[116] walking speed,[116;117] muscle strength and HHS scores.[117] Muscle strength and weight-bearing exercises compared with exercises like commonly performed in the acute phase at the hospital, were more effective on self-reported physical functioning and muscle strength.[118] Supervised ROM and strength exercises were more effective in improving muscle strength than both home exercises and no exercises.[119] Thus the review showed that different kinds of interventions have been performed having effects evaluated by various aspects of physical functioning. However, it seemed that effect between the groups on walking capacity was found in those programs where training was performed in weight-bearing position and/or when the patient's endurance capacity was challenged.[110;112;116;117]

Recovery of physical functioning after THA is the topic of this thesis, especially recovery of walking. My colleagues and I assumed it is important for the patients with THA to be able to walk longer distances, pass hindrances without falling, walk up and down hills, and walk fast. For example, walking speed is crucial for crossing a traffic intersection safely. From theory of motor control it is suggested that in order to optimize walking skills, training on walking skills is essential.[120] In line with this, the principles of specificity training also claims that the closer the training approaches the task that is to be improved, the better will be the outcome.[121] Among the prior studies there was lack of interventions approaching walking skills while training in daily ambulatory activities. In general, there has been only sparse focus on systematic training aimed to improve walking skills in prior research. This inspired me and my colleagues to develop and examine the effect of a walking skill training program. Thus, the present study was evaluating a new exercise program for patients with THA.

Table 2. Effects of physiotherapy exercise on physical functioning started earlier than 3 months after total hip arthroplasty in studies published before 2009

Citation	Partici-pants	Time of intervention	Comparisons of interventions	Content of interventions	Measures	Follow-up	Results
Hesse et al (2003)[110]	n = 80	Starting at the rehabilitation (rehab) clinic, lasting for 10 days	(1) Treadmill training with partial body weight support and usual physiotherapy (PT) (2) Usual PT	(1) Treadmill walking for 25-35min (2) Passive hip and knee joint mob, strength exercises, walking, stair climbing	Harris hip score (HHS), hip ROM, gait velocity, gait symmetry, abductor muscle strength	Immediate, 3 and 12 months	Significant difference in favor treadmill group on HHS, strength, hip ROM, gait symmetry
Suetta et al (2004)[111]	n = 36	From 1week post-operatively (PO), lasting for 12 weeks	(1) Standard rehab at home (SR) (2) SR + electrical stimuli (ES) (3) SR + resistance training (RT)	(1) Exercises in supine, seated and standing (2) ES on quadriceps (3) RT for quadriceps in supine	Walking speed, stair climbing, sit-to-stand, muscle strength, muscle mass	5 weeks, 12 weeks (imme-diate)	Significant difference in favor RT group on muscle strength and sit-to-stand
Munin et al (1998)[115]	n = 26	From 3rd or 7th PO day, lasting for 2 weeks	(1) Rehab started at day 3 (2) Rehab started at day 7	Rehab program: 2 h of PT and 2 h of occupational therapy daily. Content not described	Functional status and independence, length of stay, costs	Immediate and at 4-month follow-up	No significant differences between groups
Mahomed et al (2008)[114]	n = 115	From 6th PO day, lasting for 2 weeks	(1) Inpatient rehab (2) Home-based rehab	Content described in an appendix which was not found	WOMAC, SF36, patient satisfaction questionnaire	At 3 and 12 months	No significant differences between groups
Maire et al (2004)[112]	n = 14	From week 1 to week 7 after surgery	(1)Arm-interval exercises and standard rehab (SR) (2)Standard rehab	(1) Arm-interval program with arm ergometer and with progressive loads (2) Muscle strength, ROM, aquatics, walking	WOMAC, 6MWT, incremental exercise test	Immediate and 12 months after surgery	Significant differences in favor arm-interval group on cardio responses, WOMAC, 6MWT
Galea et al (2008)[113]	n = 23	From week 8 to week 16 after surgery	(1) Supervised exercise (2) Home exercise (same program)	Figure-of-eight path walk, sit to stand, climbing steps, single-leg stance, hip ROM, heel raise, side stepping	6MWT, TUG, stair climbing, ROM, pain, walking WOMAC, quality of life (QOL)	Immediate	No significant differences between-groups

Table 3. Effects of physiotherapy exercise on physical functioning started later than 3 months after total hip arthroplasty in studies published before 2009

Citation	Partici-pants	Time of intervention	Comparisons of interventions	Content of interventions	Measures	Follow-up	Results
Patterson et al (1995)[116]	n = 20	From 6 months to 9 months after surgery	(1) Aerobic dance (2) No exercises	(1) Enjoyable weight-bearing activities: Supervised walking, ROM and aerobic-type dance routines (music)	Cardiovascular capacity tested while walking on treadmill, walking speed	Immediate	Significant differences in favor aerobic dance group on exercise capacity and walking
Trudelle-Jackson & Smith (2004)[118]	n = 34	From 4-12 months PO, lasting for 8 weeks	Both groups performed at home: (1) Strength and weight-bearing exercises (2) isometric and ROM exercises in supine	(1) Sit to stand, heel raise, knee bends, single-leg stance, knee raises, side and back leg raises, pelvic raising and lowering (2) Non-weight-bearing exercises of hip, knee and pelvic muscle	Muscle strength, postural stability, physical function (hip questionnaire HQ-12), fear of falling	Immediate	Significant differences in favor weight-bearing group on HQ-12, muscle strength, postural stability
Unlu et al (2007)[119]	n = 26	From 12-24 months PO, lasting for 6 weeks	(1) Supervised exercise (2) Home exercise (3) No exercise	(1) and (2): ROM and muscle strength exercises	Abductor strength, gait speed, cadence	Immediate	Significant differences in favor supervised group on strength
Jan et al (2004)[117]	n = 53	From more than 1.5 years PO, lasting for 12 weeks	(1) Home exercise program (2) No training	(1) Daily exercises of hip flexion ROM, strength, 30-min walk	Muscle strength, pain, HHS, walking speed	Immediate	Significant differences in favor exercise group on muscle strength, HHS and walking speed

3 AIMS OF THE THESIS

The overall aim of this thesis was to examine the recovery of physical functioning in patients with hip OA during the first year after THA.

The specific research objectives of Papers I - III were:

1. To examine the desires of a group of patients regarding improvements in physical functioning before they underwent THA and at three and 12 months after surgery	Paper I
2. To examine the changes in physical functioning assessed before surgery, at three and 12 months after surgery by performance-based and self-reported measures, and to examine which preoperative measures of physical functioning could predict walking distance outcomes at three and 12 months after THA	Paper II
3. To examine the immediate effects of a walking skill training program on walking, stair climbing, balance, self-reported physical functioning, pain, and self-efficacy, compared to a control group without supervised physiotherapy, and to examine whether the effects persisted 12 months after surgery	Paper III

4 MATERIALS AND METHODS

4.1 Ethics

One important ethical principle followed in this thesis was the principle of informed consent.[122;123] Patients scheduled for THA surgery received written and verbal information about the study. They were asked to voluntarily participate in testing before surgery and several times during the first postoperative year and in a training program starting three months after surgery. Furthermore, they were informed that they could withdraw from the study at any time without stating a reason and without any negative consequences for their further treatment and routine consultations. A written informed consent was signed prior to participation.

Another ethical principle to consider is the burden and risk for the patients related to the assessments and participation in a study.[122;123] It was considered that the assessments would not harm the patients and that it was safe to participate in the walking skill training group. The physiotherapist running the group had great attention to the fall risk and adverse effects.

The principle of confidentiality was followed.[122] In the data set, personal identifications were replaced by a code. A list relating the codes to the personal identification was kept separate from the data in a locked cabinet. It was not possible to identify the individual patient from the data in the publications.

This project was carried out in accordance with the principles outlined in the Declaration of Helsinki. The study was approved by the regional Committee for Medical Research Ethics in Norway and the Norwegian Social Sciences Data Services (NSD). The effect study was registered online at Clinical-Trials.gov.

4.2 Design and sample size estimation

The present thesis reports data from a prospective, longitudinal study following patients with hip OA from hospitalization the day before THA surgery and up until one year afterwards. Assessments were performed four times; before surgery, and at three, five and 12 months after surgery. Two physiotherapists recruited the participants, and one of them performed all the follow-up assessments. At three months the patients were randomized to either a training group or a control group that received no training. The physiotherapist, who performed the assessments, was blinded for prior assessment scores and group allocation.

In Papers I and II the preoperative data and the data collected at three and at 12 months postoperatively were analyzed. Additionally, in Paper III a RCT design was used, analyzing the data from three, five and 12 months after surgery for two groups. The patients were assigned either an exercise group or a control group with no exercise. The randomization procedure at three months was as follows: 70 opaque, sealed envelopes, each containing a folded piece of paper with a note that assigned them to either the training or control group, 35 for each group, were prepared beforehand and mixed. An envelope was drawn and opened for each patient, and the patient was informed immediately as to group allocation.

The sample size was estimated to reach an adequate statistical power to examine the effect of the walking skill training program (Paper III). The primary outcome was the distance walked during six minutes (6MWT). For the sample size calculation a difference between the groups of 50 meters was considered to be clinically relevant,[124] and the standard deviation (SD) was set to 70 meters according to the variability reported in a prior study.[73] The statistical power was set to 80 % and the probability level to 5 %.[125] In addition, a drop-out rate of approximately 10 % was expected, and 70 patients were calculated to be appropriate.

4.3 Recruitment of patients

The participants in this thesis were consecutively recruited from two Norwegian hospitals in the Oslo area when they were hospitalized prior to THA surgery. Approximately 600 patients were operated for THA at the hospitals during the inclusion period from October 2008 to June

2010. Inclusion criteria for the study were primary OA of the hip[14] and scheduled for THA surgery. The OA diagnosis was set by an orthopaedic surgeon and based on both clinical symptoms and radiographs.[14] The patients' residence had to be within a radius of no more than 30 kilometers to the hospital in order to be able to attend the training sessions. Exclusion criteria were OA in a knee or both hips that restricted walking capacity, a neurological disease, e.g. stroke, multiple sclerosis, or Parkinson's disease, a heart condition or disease that restricted training, dementia, drug abuse, or inadequate ability to understand and read the Norwegian language. Approximately 250 patients had residence close to the hospitals and were eligible for inclusion in the study. Some of those were excluded by the exclusion criteria, and others were missed because of the busy time schedules at the hospitals (number not registered).

4.4 Measurements

Personal information was collected and used to describe the material. To measure the patients' course and outcomes of physical functioning after THA both performance-based measures and self-reported measures, which are questionnaires, were used at all assessment times. The assessor performed a control to gauge the patients' replies to all items in the questionnaires and avoid missing data. Together, the measurements captured the different components of the ICF model, i.e. Body Functions and Structures, and Activities and Participation. An overview of the registrations used in the papers, and how the outcomes were classified into the ICF components, is listed in Table 4.

Table 4. Overview of descriptive variables and outcome measures of physical functioning in the papers. The measures are classified into the International Classification of Functioning, Disability and Health (ICF) components Body Functions and Structures (BFS) and/or Activities and Participation (AP)

Personal variables and outcome measures of physical functioning	**ICF component**	**Paper I**	**Paper II**	**Paper III**
Personal variables:				
Age		x	X	x
Sex		x	X	x
Body Mass Index		x	X	x
Education		x	X	x
Comorbidity		x	X	x
Cohabiting status		x	X	x
Type of prosthesis (Exeter/Spectron)		x		x
Previous prosthesis (hip/knee)		x		
Pain at night		x		
Previous physical activity level		x		
Physiotherapy 0-3 months		x	X	x
Physiotherapy 3-5 months			X	x
Complications				x
Reported falls				x
Adverse events from the intervention				x
Performance-based outcome measures				
6-min walk test	BFS		X	x
Stair climbing test	BFS		X	x
Figure-of-eight	BFS		X	x
Index of Muscle Function	BFS		X	x
Active hip ROM in flexion	BFS			x
Active hip ROM in extension	BFS			x
Active hip ROM in abduction	BFS			x
Active hip ROM (flexion+extension)	BFS		X	
Self-reported outcome measures				
Harris Hip Score	BFS, AP		X	x
Self-efficacy	AP			x
HOOS Symptoms	BFS		X	x
HOOS Pain	BFS		X	x
HOOS Activities of daily living	AP		X	x
HOOS Sport/Rec	AP		X	x
HOOS Quality of life	AP		X	
Patient-Specific Functional Scale		x		x

Papers I and II: Assessments performed before surgery, at three and 12 months after surgery.
Paper III: Assessments performed at three, five and 12 months after surgery.

Personal variables

On the first preoperative assessment, a questionnaire was used to collect socio-demographic data including personal factors such as age, sex, height, weight, educational level, comorbidities, cohabitant status, self-evaluated level of physical activity, prosthesis type, pain at night, and participation in physiotherapy. BMI was calculated from self-reported height and weight (kg/m^2).

4.4.1 Performance-based measures

6-minute walk test (6MWT)

The test measures the distance in meters walked indoors at a comfortable speed for six minutes.[126] The patients walked back and forth along a flat 40-meter hospital corridor for six minutes, and the instruction was to "walk at a comfortable speed as long as you can for six minutes".[80;127] A change in walking distance of 50 meters has been proposed to be of substantial clinical relevance.[124]

6MWT is considered to be a useful measure of submaximal exercise capacity [126] in subjects with OA and THA. The test is easy to administer, safe, better tolerated and more reflective of activities of daily living than other walk tests,[128;129] and it is an indicator of ability to ambulate in the community,[130] such as safely crossing a traffic intersection. The 6MWT has a strong responsiveness to change over time[131]. It is found reliable and valid in older adults[130] and in patients following THA,[132] and have high correlation with other mobility tests.[127] The test is recommended used in the recent consensus report published by the OARSI[56] and it was the primary outcome measure in Papers II and III.

Stair climbing test (SCT)

In the SCT, the patients' capacity of walking on stairs is measured. The patients ascend and descend 16 steps with a step height of 16 centimeters by alternating legs as fast as they can without running. Presently, they were allowed to support themselves by holding onto the rail, but without the use of a walking aid. The time was measured in seconds. A measure of stair climbing is recommended used in the OARSI consensus report.[56]

Figure-of-eight test (Fig. 8)

The Fig. 8 test is a test of dynamic balance.[133] The patient walks within a double set of circles. The outer circles are 180 centimeters in diameter, and the inner circles are 150 centimeters in diameter. During walking the feet are placed in the 15-centimeter space between the lines. Every step on and outside the lines was registered, and more steps give a poorer score. The test is reported to be responsive and reliable[134;135] and it had a good concurrent validity when compared to other gait tests in older adults.[135]

Index of Muscle Function (IMF)

The IMF is a battery of functional performance tests. It consists of several tests yielding four separate indices: General mobility, muscle strength, balance/coordination and endurance. A patient's performance is observed and evaluated by the assessor on a 3-point scale (range 0 - 2, when 0 = no difficulty in performance, 1 = some difficulty, 2 = severe difficulty or unable to do the test).[136;137] The total score is from 40 points (worst) to 0 (best). IMF has an acceptable reliability and concurrent validity when compared to other performance-based tests in patients with OA.[137]

Active hip range of motion (ROM)

Hip ROM was measured by a goniometer. The patients were tested in supine position with the hip in zero position for abduction, adduction, and rotation. We measured the degrees of flexion, extension, and abduction according to the procedures of Norkin and White.[138] In Paper II the hip flexion and extension were summarized and reported as the total score for active hip ROM.

4.4.2 Self-reported measures

Patient-Specific Functional Scale (PSFS)

PSFS is a patient-specific instrument developed to provide a method for eliciting, measuring and recording descriptions of patients' disabilities.[59] The patient's functional limitations are identified by asking the following question: "Today, are there any activities that you are unable to do or have difficulty with because of your problem?" The patient responds by describing his problem in free text.[58-60] To record descriptions of what the patients wanted to improve in the physiotherapy context we modified the original question and asked the patients the following: "Which activities do you consider important to improve?" As in the PSFS, they were asked to identify 1-3 activities. The question was tested on some random patients at the hospital before the study started. The patients gave clear and concise answers, which was interpreted to signify that the question was easy to understand.

In Paper I, the modified PSFS was used to investigate functional improvements desired by the patients before surgery and in the first year after surgery. Only the modified question was used and not the scale. The modified question was also used by the physiotherapists conducting the walking skill training program to guide their approach to the patients' desires (Paper III). They were not shown their previous answers in the subsequent assessments at three and 12 months.

Harris Hip Score (HHS)

The HHS is the most widely used disease-specific measure of hip disabilities before and after THA.[139] The physiotherapist administered the test in the form of a structured interview with the patient. The domains assess pain, physical function, deformity, and gait.[55;140] Pain and function receive the heaviest weighting with 40 and 47 points, respectively. The rating scale is from 0 (worst) to 100 points (best). The HHS is considered to have good validity and reliability.[139] At the respective hospitals a cut-off score of 62 points on HHS, also together with other criteria, is used in the decision-making for timing of surgery.

Hip dysfunction and Osteoarthritis Outcome Score (HOOS) LK 2.0

The HOOS is a disease-specific questionnaire which is developed to evaluate self-reported problems with hip disabilities with and without hip OA and after THA.[54;141] The HOOS is an extension of the frequently used WOMAC LK 3.0 questionnaire. It includes all the questions of the WOMAC; three subscales addressing symptoms (five items), pain (10 items), and activities in daily living (ADL) (17 items). Additionally, there are two subscales with questions about function in sport and recreation activities (Sport/Rec) (four items) and hip related quality of life (QOL) (four items).[54] Each item is given a score from 0 (no symptoms) to 4 (extreme symptoms) and the scores reach from 0 (worst) to 100 points (best).[140] The scoring was done according to the "HOOS LK 2.0 User's Guide" (www.koos.nu). HOOS has been considered to have adequate measurement properties of validity and reliability, and to be responsive to change in patients with THA.[54;141] We applied the Swedish HOOS 2.0 version and translated it into Norwegian according to standard procedures (Appendix).[142] Since Norway and Sweden are culturally close, the psychometric qualities of the Norwegian version were not tested. Recently, another translated Norwegian version of the HOOS 2.0 has been published online (www.koos.nu), and this translated version is very much alike the Norwegian version used in this thesis.

Self-efficacy measure

Self-efficacy in activities is assumed to be adequately evaluated when the questions are tailored to the actual domains of interest.[143] Based on clinical experience, the literature, and the author's previous research that revealed difficulties in stair climbing and walking more than two kilometers nine months after surgery in patients with total knee arthroplasty (TKA),[144] my co-authors and I developed ten questions. The questions addressed usual walking and transfer activities that were considered relevant for the patients with THA (Appendix). Each item was attached to a scale anchored from 0 (very uncertain) to 10 (very certain). The responses were calculated in a sum score from 0 (worst) to 100 (best). In the material, the internal consistency of the responses to the items was found to have a Cronbach's alpha of 0.78.

Registration of adverse events

In Paper III, the physiotherapist registered adverse events, such as injuries and falls, during the training sessions. At the 12-month assessment, patients filled in a questionnaire to register whether they had experienced any falls, dislocation of the hip, loosening of the prosthesis, deep vein thrombosis, or thrombophlebitis the last seven months.

4.5 Total hip arthroplasty surgery and physiotherapy at the hospital

The two hospitals that recruited patients to this thesis used two different types of hip prostheses: the Exeter prosthesis [145] and the Spectron prosthesis.[146] A posterolateral surgical approach was used for both types. A curved incision posterior to the m. gluteus medius was performed, centered on the posterior aspect of the greater trochanter. The incision was about 13 centimeters long. The fascia lata was incised and the gluteus maximus was split. Further, the short external rotators were detached and reattached during closure.[147] The posterior capsule was sutured. Both the acetabular and femoral components were cemented. While in hospital, all the patients followed the same anesthetic procedure during and after surgery, which included intra-articular local injection analgesia.

There were no postoperative restrictions with respect to weight-bearing. To prevent dislocation, the patients were informed to avoid hip flexion beyond 90°, hip adduction beyond the neutral position, and hip internal rotation beyond 0° in the operated hip for the first three months after surgery.[148] There were no differences in change scores between the patients with the different prosthesis, and the two prosthesis types are reported as one group.

During hospitalization the patients received daily physiotherapy according to usual care at the hospitals. The physiotherapy sessions consisted of exercises in bed to prevent thrombosis and joint stiffening and to facilitate muscle activation. Walking on flat floor with a supporting device and stair climbing were also performed. The patients were informed that they could attend to usual physiotherapy the first three postoperative months at an inpatient rehabilitation institution or outpatient clinic.

4.6 The walking skill training program

Because of postoperative pain, swelling, and restrictions on hip motion through the third postoperative month, it was considered appropriate and safe to start the walking skill training program at three months after surgery when these restrictions were lifted. The aims of the training program were to restore and optimize physical functioning in patients with THA, which to a large extent is related to the walking ability.

The physiotherapy training was inspired by motor control theory.[120] Motor control involves interplay between the muscle groups that moves and stabilise joints. It was believed that improvements in walking are better achieved if the patients practiced exercises that closely approximated the activity to be improved, with variations in how to perform the activity and with several repetitions.[120] Thereby, the program was based on two main principles. First, by training daily ambulatory activities also training of muscular strength, flexibility and endurance were incorporated. Second, by the physiotherapist's guidance and feedback the patients were taught to refrain from habitual unloading of the affected hip[44-46] and find better ways to walk (Paper III). In accordance with this the main attention in the training program was on training walking skills.

The training program consisted of 12 sessions; training was performed twice a week and each session lasted for about 70 minutes. The intensity of the training was to load the operated limb as much as tolerated. In intervals the intensity was that high as to get short of breath, but the patients should be able to talk while exercising.

First, there was a warm-up period for about 10 minutes that consisted of standing with weight transfers, sidesteps with arm swing, and walking in a circle at different speeds and step lengths. Next, muscle strength, hip flexibility, balance, coordination and endurance were trained by different functional tasks, such as rising up from and sitting down on a chair, performing lunges, single-leg stance on foam balance pads, and walking along an obstacle course consisting of different obstacles that should be stepped onto, along and down from, ascending and descending a step forward and backward and at different heights and speeds; walking on stairs; walking on a flat floor at different speeds, with different stride lengths, and with turns; and throwing a ball to each other while moving around (Figure 4). These different exercises lasted for about 50 minutes. At the end of the training session, the patients performed stretching exercises of the calf, leg, thigh, neck, and shoulder muscles for about ten minutes (described in detail in Paper III).

The difficulty of the exercises was individualized to each patient's level of physical functioning, the individual patient's wish for improvement and how the individual patient progressed over time. During the tasks, the physiotherapist guided the patient to load on the prosthetic hip and to use the leg properly. Continuous feedback was given to the patients. When a patient managed to perform the task, a progression of the level of performance and capability was added. A more extensive description of how the walking skill intervention was practiced is reported in a submitted paper.[149] The results suggested that the walking skill intervention was more individually adjusted than described in Paper III and that learning was an essential trait of the program.

With kind permission from the involved patients.

Figure 4. Images from the walking skill training group.

4.7 The regime for the control group

The control group was not allocated to receive any supervised physiotherapy during the time span between the assessments at three and five months. If they were receiving physiotherapy at three months after surgery, they were asked to discontinue this physiotherapy. They were, however, encouraged to stay generally active and continue with the training they had learnt at the hospital or at the physiotherapist after discharge. All but one of the patients in the control group reported that they had been doing training on their own and walks for several times a week (data not shown) (Paper III).

4.8 Analysis

In Paper I the ICF classification system was used to manually code the improvements desired by the patients. This coding was performed according to standardized linking rules.[41;150] All the desires could be grouped under Part 1, Functioning and Disability. First, patient desires were classified under the Body Functions and Structures component, or Activities and Participation component, and thereafter by chapters at the 1st level. Further, patient desires were classified under the category at the 2nd level and, at last, under the appropriate ICF code at the 3rd level of classification.[40] The total number of ICF-coded responses at each assessment was counted, and the proportions of responses in each category were calculated as a percentage of the total number of responses.

The statistical software program SPSS, version 18.0 for Windows, was used for statistical analysis. The level of statistical significance was set at 5 %. Non-parametric statistic presented as median with 25th and 75th percentiles was used when analyzing changes in number of responses over time, as the data were not normally distributed (Paper I). In Papers II and III the data were approximately normally distributed and parametric statistics were performed and presented with means and 95 % confidence intervals (CIs). An overview of the statistical analyses used in the different papers is presented in Table 5.

Table 5. Overview of the statistical methods used in Paper I, II and III.

Statistics	Paper I	Paper II	Paper III
Descriptive statistics			
Means (95 % CI), proportions and frequencies	x	x	x
Statistical analysis of differences			
Exploring within-group differences:			
Paired sample *t* test			x
Friedman test	x		
One-way repeated measures analysis of variance (ANOVA)		x	
Exploring between-group differences:			
Chi^2 test			x
Independent sample *t* test		x	x
General linear model analysis of covariance (ANCOVA)			x
Statistical analysis of relationships			
Exploring relationships:			
Pearson correlation coefficient (r)		x	
Multiple regression analysis		x	

Descriptive statistics for continuous variables were presented as mean values with 95 % CIs. For categorical variables, proportions and frequencies were calculated.

Within-group changes in physical functioning over time were analyzed either by paired sample *t* tests or by repeated-measures analysis of variance (ANOVA) (Table 5). In the ANOVA test participation in the exercise program was included as a covariate. A Greenhouse-Geisser correction was applied if Mauchley's test of sphericity was violated. Bonferroni corrections were run at the post-hoc tests (Paper II).

Between-group differences in Paper III were examined by chi-square test in categorical variables. In continuous variables between-group differences in change of physical functioning were examined in continuous variables by independent sample *t* test and analysis of covariance (ANCOVA), and the data were adjusted for sex and pretest scores when analyzing the effects of therapy (Table 5). The principles of intention-to-treat (ITT) were followed,[151] and data from all randomized patients were included in the analysis. We assumed that the missing data of four patients who dropped out of the study were missed at random, and the score at the last observation was carried forward to replace the missing data. The partial eta-squared effect sizes were also calculated. A partial eta-squared effect value between 0.01 and 0.05 is considered a small effect, between 0.06 and 0.13 a moderated effect, and between 0.14 and 1 is considered a large effect.[152]

To examine relationships between the different candidate predictors for the multiple regression analysis in Paper II, the Pearson's correlation coefficient was used. In the multiple regression analyses the dependent variables were 6MWT at three and 12 months after surgery, and independent variables were sex and preoperative variables which correlated significantly to the dependent variable in the bivariate analysis. If the correlation between the independent variables was more than 0.7, they were assumed to measure the same dimensions, and only the one with the highest correlation with the dependent variable was entered into the regression analysis.[153] It was controlled for age, sex, pain (HHS), and, in the 12-month analysis, for participation in the training group.[154] A manual backward stepwise procedure was performed to select the subset of predictors with statistically significant contributions. The regression coefficients were reported with 95 % CI.

5 RESULTS

5.1 Paper I

Functional improvements desired by patients
before and in the first year after total hip arthroplasty

The objective was to examine the desires of a group of patients regarding improvements in physical functioning before they underwent THA and three and 12 months after surgery. Ninety-two patients were included preoperatively, but 24 withdrew from the study at three months and four at 12 months, leaving 64 patients with mean age of 65 years to complete all three assessments. The responses of 34 women and 30 men were reported in the study.

There were a total of 333 responses, all classified under Part 1 of the ICF, Functioning and Disability. Eighty-eight percent of the responses fell into the Activities and Participation component. More than half of the responses at all the assessment times were coded into categories of Walking (d450), Moving around (d455), and Recreation and leisure (d920). At three months after surgery there was a decrease to 12.9 % of the responses classified into the category of Recreation and leisure (d920), compared to 24.8 % preoperatively and 25.4 % at 12 months after surgery. There was an increase to 16.5 % of responses classified into the category of Dressing (d540) at three months, compared to 6.9 % preoperatively and 6.3 % at 12 months. The total number of responses at each assessment time decreased during the year from 145 responses preoperatively to 79 responses at 12 months. The number of responses reported by the subjects classified into the Activities and Participation component were decreasing over time ($P < 0.001$).

In conclusion, the number of responses reported by the patients decreased during the first postoperative year, while the content of the desires before and 12 months after THA were mainly concerned with the ability to walk and participate in recreation and leisure activities. At three months, however, there was a tendency that the patients were more concerned about the immediate problems with putting on socks and shoes.

5.2 Paper II

Recovery and prediction of physical functioning outcomes during the first year after total hip arthroplasty

The objective was to investigate recovery course and outcome of physical functioning in patients with OA during the first year after total hip arthroplasty, and to predict postoperative walking distance outcomes from preoperative measures. The inclusion period was prolonged when recruitment to the training study was completed, and 11 more patients were included in the study. One hundred and three patients were assessed preoperatively, but 15 patients, who were mostly women with lower scores on physical functioning than the others, withdrew from the study before three months, leaving 88 patients to be assessed. Twenty-four patients withdrew from the study at 12 months, leaving 64 at the 12-month assessments.

In the performance-based measures, the patients improved in 6MWT from preoperative mean 401 meters (95 % CI 377, 425) to 437 (416, 458) meters at three months ($P < 0.01$) and further to 512 (490, 534) meters at 12 months after surgery (17 %; $P < 0.001$). The 6MWT improved from preoperative to three months by 9 % and from three months to 12 months by 17 %. In SCT the patients improved from 14 (13, 16) seconds preoperatively to 13 (12, 13) seconds at three months ($P = 0.05$) and to 11 (10, 12) seconds at 12 months after surgery ($P < 0.001$). The SCT improved from preoperative to three months by 7 % and from three months to 12 months by 15 %. The other performance-based measures only improved from three to 12 months: by 30 % in Fig. 8 from 10 (6, 13) steps to 7 (4, 10) steps ($P = 0.001$), by 33 % in IMF from 12 (11, 14) points to 8 (7, 10) points ($P < 0.001$), and by 12 % in hip ROM from 84 (81, 87) degrees to 94 (91, 98) degrees ($P < 0.001$).

In all the self-reported measures the mean improvements varied from 49 % to 127 % from preoperative to three months postoperatively ($P < 0.001$), and the improvements from three to 12 months postoperatively varied from 8 % to 23 % ($P < 0.001$). Those with worse preoperative scores in 6MWT achieved the largest changes at three and 12 months. Those with high preoperative 6MWT scores needed longer time to regain their walking capacity, but at 12 months they had regained and increased their 6MWT score and had a better walking capacity than those with worse preoperative scores. Age, sex, and preoperative 6MWT and hip ROM predicted 6MWT outcomes at three and 12 months postoperatively ($P \leq 0.01$). The total adjusted models explained 37 % of the variance at three months and 47 % at 12 months ($P < 0.001$).

In conclusion, different patterns of recovery were revealed depending on the assessment methods applied. The performance-based measures of physical functioning improved gradually during the first postoperative year, while the self-reported measures showed large early improvements, but little further improvements from three to 12 months. Those who had the worst preoperative scores in 6MWT gained the most from surgery, while those who had the best scores before surgery also had the best final outcomes at 12 months. Younger age, male sex, and better scores of walking distance and hip flexibility before surgery predicted better scores in walking distance both at three and 12 months after surgery.

5.3 Paper III

Effect of a walking skill training program in patients who have undergone total hip arthroplasty: Followup one year after surgery

The objectives were to examine the immediate effects of a 12-session walking skill training program of weight-bearing activities performed between three and five months after surgery, compared to a control group without supervised physiotherapy, and to examine whether the effects persisted 12 months after surgery. Sixty-eight patients were randomized to the training (n = 35) or control (n = 33) groups three months after surgery. Three patients withdrew at the assessments at five months and one patient at 12 months. The data at the last observation were carried forward for these patients.

There were significant treatment effects in favour of the training group from pretest at three months after surgery to immediately after the intervention at five months (posttest 1) on 6MWT of adjusted mean difference 52 meters (95 % CI 29, 74; $P < 0.001$), on SCT of -1 (-2, 0) seconds ($P = 0.01$), on Fig. 8 test of -3 (-5, 0) points ($P = 0.02$), on IMF -3 (-4, -1) points ($P = 0.001$), on active hip ROM in extension 2 (0, 4) degrees ($P = 0.02$), on HHS 3 (0, 7) points ($P = 0.05$), and on self-efficacy 6 (0, 11) points ($P = 0.04$). The differences between the groups from pretest to 12 months (posttest 2) persisted on 6MWT of adjusted mean 52 meters (95 % CI 24, 80; $P < 0.001$) and on SCT of -1 (-3, 0) seconds ($P = 0.05$). Twenty-three patients (66 %) in the training group and five (15 %) in the control group increased their walking distance by ≥ 50 meters to posttest 1 compared to their pretest distance ($P < 0.001$), while 26 patients (74 %) in the training group and 15 (46 %) in the control group had increased walking distance by ≥ 50 meters at 12 months compared to their pretest distance ($P < 0.001$).

In conclusion, the walking skill training program was effective in improving walking distance immediately after the intervention and the effect persisted one year after THA surgery.

6 DISCUSSION

This thesis examined the recovery of physical functioning in patients following THA. The results showed that functional improvements desired by the patients were to become able to walk long distances and to participate in recreation and leisure activities[155] (Paper I). The patients had improved in all the outcome measures of physical functioning one year after THA compared with preoperatively.[156] Patients with the worst preoperative scores on 6MWT improved most with respect to walking capacity, but those with the best preoperative scores still had the highest scores one year after THA. Those who had lower scores on the 6MWT and hip ROM before surgery, and additionally were female and of higher age, were at risk of poorer outcome in the 6MWT after surgery (Paper II). Training walking skills showed an immediate effect in improving walking distance and this effect remained 12 months after surgery[157] (Paper III).

A specific discussion of the aims of each paper was thoroughly presented in the different papers. From a patient's perspective, the issues of most concern after THA are regaining the ability to walk and participate in recreation and leisure activities (Paper I). Therefore, in the discussion below I will emphasize the recovery of walking and participation in recreation and leisure activities and the measures used to assess these aspects of physical functioning.

6.1 Methodological considerations

6.1.1 Internal validity

All the studies in this thesis had a longitudinal design. The purpose of a longitudinal design with assessments taken prospectively on several occasions is to document and describe the nature of a phenomenon through a systematic collection of data.[123] Therefore, the study design in the present thesis is deemed appropriate for examining the research questions posed. However, to get a more nuanced picture of the course of recovery in Paper II, it would have been preferable with more systematic time intervals between assessments, e.g. intervals of three months. Moreover, another relevant question is whether the data at 12 months in Papers

I and II were influenced by the participation in the 6-week walking skill training program that started three months postoperatively. Obviously, there was a difference between the training and control groups, and therefore it was controlled for participation in the training group in the statistical analysis (Paper II). With respect to the desires for improvement reported at 12 months (Paper I), I have looked closely into the data in order to find out whether there were any systematic differences between the groups. I was not able to identify such a trend. Nevertheless, one may question whether the desires to improve balance at 12 months could have been influenced by experiences from training balance in the walking skill training group.

In Paper III, a RCT design was used to examine the effects of a walking skill training program. This design is regarded as the gold standard for examining treatment efficacy[125;158] and is a relevant design for examining causality, such as effectiveness of treatment compared to a control group with no treatment.[123] The CONSORT 2010 checklist was followed when reporting results from the RCT (www.consort-statement). In the PED*ro* database the study scored 8 of 10 items, and the missing scores were on random allocation and blinding of the subjects and therapists (www.pedro.org.au) (Paper III).

Therefore, some aspects have to be discussed, e.g. the randomization procedure. Prior to randomization, sealed, opaque envelopes were prepared with equal numbers of envelopes assigning to the walking skill group and the control group. Certainly, this ensured that there would be equal numbers included in the two groups, but on the other hand there was not necessarily an equal probability to be assigned into the two groups for the last patients being included. Thus, the randomization procedure should have taken this into account, but I do not believe this presented a great problem. In relatively small samples, as in Paper III, it can be problematic if the groups differ on important aspects. Matching the patients on age and sex could have solved this problem. To correct for inequalities between the groups, we have adjusted for preoperative measures and sex in our statistical analysis. We consider this an appropriate way of handling the problem of inequality between groups that probably strengthened the internal validity of the study.

Another factor that may influence the internal validity in the papers is the critical issue of assessor blinding.[159] In Papers I and II there was a long span of time between the assessments at preoperative, three and 12 months postoperatively and it is unlikely that either the patients or the assessor remember the prior scores, nor did they have access to them. This was probably very helpful in obtaining valid data. In Paper III, the patients obviously knew if they had been in the walking skill program or not, but the assessor did not know which group the patients were allocated to. The data were collected in a separate building from the training group sessions, and the patients were instructed not to talk about group allocation with the assessor. As far as I know, the blinding of the assessor was successful. But with respect to patient awareness of what kind of intervention they received, the present study shares the destiny of other non-pharmacological effect studies, as in most cases the only option is to blind the assessor.[159] However, another limitation is that I was one of two physiotherapists that provided the intervention. The attention from the researcher having great interest in demonstrating effect of an experimental program may have substantial effects because of the patients' eagerness to please the researcher.[160] A sham exercise group, e.g. a group receiving the non-weight bearing exercises usually performed in the early postoperative phase and believed not to be effective three months after surgery, could have reduced the problem.

One more factor that may influence the internal validity of the effect study is the patients' compliance to the intervention.[125] The training program was conducted by the researcher, and this assured that the patients in the training group participated in all parts of the program and trained at the proper intensity. There was also a high adherence to the exercise sessions in the exercise group. The patients attended 12 sessions, except four patients who attended between eight and 11 sessions. Thus, I can be certain that the patients actually trained according to the protocol.

All in all, I consider the designs used in this thesis appropriate for answering the different research questions. The blinding of the assessor, the patients' high compliance to the content of the training program and the high adherence to the exercise sessions strengthened the validity of the study. However, there are uncertainties as to whether experimenter bias and the lack of blinding of the patients have influenced the results in Paper III and how the participation in the training program influenced the assessments at 12 months in Papers I and II.

Assessment methods

One relevant question to discuss is whether the measurements chosen in this thesis were able to reflect the patients' recovery of physical functioning and the differences between the groups. When the study started, we did not know what improvements in physical functioning the patients would desire and measurements that are commonly used in this field were chosen. In Paper I, we showed that the patients were concerned about ability to walk long distances and participate in recreational and leisure activities, but the items in the self-reports only reflected these desires to a small extent. Thereby, the question can be raised whether appropriate measurements were chosen to reflect the patients' concerns. Accordingly, this will be discussed further.

We applied both performance-based measures and self-report questionnaires to assess physical functioning. Recently, the OARSI has reached consensus and published a set of performance-based tests of physical functioning recommended for use in people with hip OA and THA.[56] The performance-based assessments were considered by the expert panel to be complementary to self-reports. Among the five tests they recommended, two of them were included in this thesis: the 6MWT and a measure of the patients' ability to walk on stairs. Thus, the measures applied in the present thesis were in accord with the OARSI group recommendations. However, the patients hoped to walk long distances outdoors (Paper I) and the training program was aimed to mirror the demands of outdoor walking and included training that challenged ambulatory balance, strength, flexibility and endurance (Paper III). The ability to walk outdoors is likely to be more challenging than walking on a flat floor as assessed by the 6MWT. If I were to do this study again, I would also include assessments of more advanced walking abilities; this would more closely reflect the patients' desires and the purpose of the training program. Nevertheless, the 6MWT measures walking capacity, and if walking capacity improves, it is likely that a better capacity will enable patients to walk longer distances. Thus, I consider the 6MWT has assessed a relevant aspect of walking, but it could have been complemented with more advanced measures of walking ability. Moreover, a study examining how the walking skill program was performed in practice found that an essential aspect of the program was teaching the patients to normalize their gait patterns.[149] It is reasonable that, e.g., less limping will indirectly result in better scores on 6MWT, but to address a possible learning effect more specifically this could have been assessed by a gait analysis.

Ideally, questionnaires should reflect the types of activities the patients consider important. The patients wanted to improve their ability to walk long distances and participate in recreation and leisure activities (Paper I). The questions in HOOS and HHS were mainly about pain and ability to perform routine daily activities, such as getting in and out of bed, going shopping, sitting and running, etc. In the recovery process, a reorientation also takes place with respect to expectations for physical functioning,[62] and the relevance of the items included in the questionnaires may thereby change for the patient during the course of recovery. For the patients in this thesis, the questionnaire topics seemed more relevant to their desires at three months after surgery than before surgery and at 12 months after surgery. The patients' desires before and 12 months after surgery focused on walking long outdoor distances and participating in leisure and recreation activities. Only the HOOS Sport/Rec addressed such wishes, but the five items included questioned the ability to squat, run, twist on loaded leg, and walk on uneven surface. Thus, only one item matches the desires of the patients in the present thesis. Therefore, HOOS and HHS may be relevant in an early postoperative phase, but not so relevant for mirroring the patients' desires or expectations of outcomes in the long run.

There was probably a problem of ceiling effects in HHS and HOOS because more than 15 % of the patients scored the highest possible scores at 12 months after surgery,[161] indicating that the questions were not challenging enough for the patients (Papers II and III). Ceiling effects have previously been shown to be a problem in HHS and HOOS.[162;163] Such ceiling effects limit the measurements' usefulness in evaluating efficacy and long time outcomes and lead to a shortcoming in the tests' ability to detect clinically relevant changes.[162;163] The consequences may lead to misinterpretations about lack of improvements and improper conclusions about effectiveness of interventions. This may have happened in this study (Papers II and III). Moreover, this can explain the difference in recovery patterns as assessed by self-reports and performance-based measures (Paper II). Paradoxically, if clinicians and researchers design training programs aimed at fulfilling the active patients' desires and expectations, they may not be able to fully evaluate the recovery outcomes by using the commonly used assessments. There may be a need of new, more challenging measurements, which could be a topic for further research.

The assessment methods used in this thesis revealed improvements in physical functioning during the first year and effects of a walking skill training program after THA. However, in future research more challenging and comprehensive walking assessments and items of more demanding functions capturing the patients' concerns should be considered.

6.1.2 External validity

The external validity in this study concerns to whom the results can be generalized.[123] This can be influenced by the selection of patients. The subjects who are willing to participate as research subjects may differ from those not willing to participate in research.[123] An appropriate question is whether the included sample of patients in this thesis were representative for patients with THA in Norway and the rest of the world in general.

There were approximately 250 patients with residence close to the two hospital that were treated with THA during the inclusion period, and it is relevant to consider whether those included to participate in the study were different from those not eligible for participation. Patients scheduled for THA were informed and asked before surgery to participate in an exercise study. Some patients were never asked to participate because of the busy work load at the hospitals. Probably, this occurred by random and did not cause any selection bias. The exclusion criteria also excluded many patients. As to be able to examine the effect of the intervention we strived to get "clean" groups without many disturbing factors, as is also done in most other studies. Therefore, patients with the highest disability were excluded from the study. Additionally, those who withdrew from the study at three months had worse physical functioning before surgery than those who continued. This may have given us a sample consisting of relatively healthy patients. Approximately the same patient sample was studied in all the papers. Our patients were aged from 45-81 years, and thus they covered a large age span. The mean age of our patients was 65 years and those treated with THA in Norway in 2012 was in mean 69 years.[37] Consequently, with respect to the patients' age, they were close to those operated in Norway.

The percentage of women registered in the Norwegian arthroplasty register was 68 %,[37] while in this thesis there was a percentage of approximately 50 % women completing the assessments at 12 months (Papers I – III). Men are known to have a better walking capacity than women,[164;165] and the men in our sample walked approximately 50 meters longer than the women (data not shown). When comparing the preoperative mean score of 6MWT (Paper II) to the preoperative score in other studies, one study reported a shorter walking distance than our patients.[80] There were also an example of a study reporting a better preoperative walking distance than our patients did, but the percentage of men and women was not given in this study.[48] Therefore, the patients in this thesis seems to be comparable to patients with THA in other studies. All in all, the results of the thesis can mainly be generalized to relatively healthy patients with THA.

6.2 Discussion of results

6.2.1 Recovery of walking and participation in activities the first year after THA

Both the recovery process and the outcome one year after surgery were examined. The walking capacity increased gradually during the first year, and at one year the patients had improved a mean of approximately 110 meters compared with preoperative measures (Paper II). This increase is consistent with prior research, where improvements from 70 to 149 meters during the first year after surgery were reported.[73;79;80] Nevertheless, the patients were still concerned about their ability to walk long distances (Paper I), suggesting that their expectations of recovery in walking were not yet fully met. Our data showed that at 12 months they had not reached the level of their healthy peers when compared to reference standards.[164-167] Consequently, although the patients' walking capacity measured by 6MWT was significantly improved, their mean walking distance did not reach the level of healthy people.

The patients hoped both preoperatively and one year after THA to participate in recreation and leisure activities (Paper I). Examples of such activities were going for long walks in the woods, hiking in the mountain, skiing and playing golf. The HOOS Sport/Rec subscale contains items about ability to squat, run, twist on a loaded leg, and walk on an uneven surface. As already discussed, the HOOS Sport/Rec subscale did not cover the activities the patients wanted to improve. Considerable improvement in the HOOS Sport/Rec score was seen already at the assessments at three months, and there was some further, but less marked improvement at the 12-month assessment (Paper II). These high scores may lead to an impression that the patients were fully recovered. However, this might not be so from the patients' view. Clinically, this may lead to a tendency to finish treatment too early. If the items had addressed the ability to, e.g., go for long walks in the woods and participate in activities of golfing and skiing, another picture of recovery of physical functioning may have been found the first year after surgery. At the least, it is unlikely that the patients would have been able to participate in such activities as early as three months. Thus, there could be a slow, but gradual improvement in participation in recreation and leisure activities during the first year, as was the case in the improvement pattern observed by the assessment of 6MWT.

Another question is whether it is likely that patients with THA can be able to resume the recreation and leisure activities they enjoyed before surgery (Paper I). From prior research, patients undergoing lower limb orthopedic procedures are known to have a high rate of sports participation preoperatively, especially in swimming, walking and golf.[168] However, by one to three years after surgery, approximately 40 % of patients had not returned to their sporting activities.[168] The largest decline was in high-impact sports, such as badminton, tennis and dancing. Another study reported that approximately 25 % of the patients were not able to return to their preferred leisure activities one year after surgery.[169] A similar trend was found in our prior study of patients after TKA. Nine months after TKA the patients reported having difficulties with strenuous and moderate activities, walking more than two kilometers, and climbing stairs.[144] However, in another study it was pointed out that a higher number of patients with OA were active in sports after THA than before the surgery.[170] Fewer patients participated in golf, tennis and jogging, but instead they had started to do less demanding activities, such as walking and aqua aerobics.[170] This suggests that, after THA, the patients can potentially be physically active, but they tend to perform less demanding activities. For the patients this might be more appropriate. It can, however, also be that more challenging activities could be tolerated by today's prostheses. For physiotherapists, more knowledge about this issue is warranted in order to give adequate advices.

6.2.2 The significance of preoperative functioning for postoperative walking

For both health professionals and patients it can be of interest to gain an indication already before surgery as to what is the plausible outcome after surgery. In this study, those with a poor preoperative 6MWT score gained the largest change score in 6MWT after surgery (Paper II). Others have also found that the patients with the worst preoperative physical functioning were most likely to have large improvements in variables of physical functioning.[93;171] On the other hand, their outcome did not reach the level of those with the best physical functioning one year after surgery (Paper II). Most of the patients improved their scores beyond preoperative measures. A prior review study has shown that the patients with better physical functioning and less pain preoperatively were most likely to achieve a good final outcome in performance-based measures of physical functioning after THA.[97] In accordance with this finding, higher self-reported preoperative walking capacity directly correlated with likelihood of being able to walk more than 60 minutes postoperatively.[172] Thus, although different aspects of physical functioning have been assessed, there seems to be a trend, also confirmed by our study (Paper II), that those having the poorest functioning before surgery have the most to gain from THA, but at the same time those having the best physical functioning before surgery will probably have the best outcome one year after THA. This raises the question whether the patients could improve their postoperative outcomes by preoperative training, or alternatively, whether those having most impaired preoperative physical functioning should be given more attention and training after surgery.

In the present thesis we found that preoperative hip ROM and walking capacity pedicted the outcome in walking capacity at both three and 12 months postoperatively when adjusted for age and sex (Paper II). Preoperative HOOS Sport/Rec was also included in the prediction analysis, but had no significance in predicting postoperative walking capacity. The results indicate that preoperative walking and hip flexibility can predict postoperative walking outcome. One relevant question is thus whether preoperative training could improve the postoperative outcome in walking. A prior study investigated the effects on walking ability from an 8-week preoperative exercise program in partial weight-bearing comprising hydrotherapy, ergometer cycling, muscle strength training, and flexibility exercises, compared to a group with no preoperative exercise.[173] A better cadence, stride length and gait velocity were found three weeks after surgery in the preoperative exercise group compared with the non-exercise group.[173] However, the preoperative training program showed no statistically significant effect on walking before surgery, but it seemed that the exercise group avoided the early decline in postoperative walking that was observed in the control group three weeks after surgery.[173] This indicated that a preoperative training program can benefit postoperative walking. However, further studies are needed to confirm this finding.

6.2.3 Effects of the walking skill training program

Both before and during the first year after THA, the patients wanted to improve their ability to go for long walks outdoors and participate in valued recreation and leisure activities (Paper I). In order to improve walking, the walking skill training was focused on doing exercises in close relation to walking ability (Paper III).[157] As in our program, Patterson et al also trained weight-bearing transfer activities, but in this case by an aerobic-type dance program.[116] An essential difference between this program and ours is probably the guided individual adjustments and learning how to move incorporated in our program.[149] However, the aerobic-type dance program had a better improvement in 6MWT than was demonstrated from our walking skill training program. One plausible reason can be that the aerobic dance program had a larger impact on the cardiovascular capacity of the patients. The role of the cardiovascular capacity for walking was shown by training on an arm ergometer cycle, where both improved measures in cardiovascular capacity and walking were found, in spite of walking not actually being specifically trained during the program.[112] Another study revealing effect on walking was the study of Jan et al,[117] performed one and a half years after surgery. The program consisted of low-impact training in non-weight bearing positions and daily outdoor walks for 30 minutes. The training group improved their walking speed of nearly 50 meters compared with a non-training control group (Table 3).

Six published RCTs examining different exercise interventions after THA were found from 2009 to date,[174-179] but none of these recent RCTs focused on training in weight-bearing or training walking skills, except for one study. In this study patients operated with hip resurfacing arthroplasty trained ambulatory weight-bearing activities and effects were examined when compared to standard physiotherapy.[179] The program had many similarities to the walking skill training program. However, it was performed at home according to a protocol, it started when discharged from hospital, and it was systematically accelerated every second week with more weight-bearing and more demanding activities, such as progressing from walking indoors to outdoors. One year after surgery the program showed effects on self-reported physical functioning, level of activity, patient selected goals and hip ROM. The outcome effect on walking was not measured in this study. A higher level of activity and positive effect in HOOS demonstrated that the program had been successful in achieving a higher level of physical functioning than the standard physiotherapy did.[179] These results from exercise after hip resurfacing arthroplasty are interesting and suggest that patients with THA can also tolerate challenging weight-bearing ambulatory activities in an earlier phase after surgery than we chose in our program.

Thus, there seemed to be support for training weight-bearing ambulatory activities in patients with THA. This apparently effective training can be significant for patients, as they hope to improve their walking ability. Moreover, improved walking ability also seems likely to enhance the patients' possibilities for participating in sport and recreation activities. In my view, future research should be performed to further elucidate the most effective methods for training walking and ambulatory skills.

7 CONCLUSION

In this thesis, recovery of physical functioning was examined in patients with OA during the first year after THA. Both before surgery and one year after surgery, the patients wanted to improve their ability to walk longer distances and to participate in recreation and leisure activities. The patients' physical functioning improved during the first year after THA. Those with poor preoperative walking distance gained most in physical functioning, but those who performed best preoperatively finished the best. Age, sex, preoperative 6MWT and hip ROM scores predicted postoperative 6MWT outcome score. The walking skill training program conducted after the usual rehabilitation period was effective in improving walking capacity immediately after the training period, and the effect still sustained one year after surgery. No adverse events occurred during the program or during the following months. These results can be generalized mainly to relatively healthy patients with THA. However, it may be questioned whether the measurements were appropriate. Because the patients' concerns to some degree were not captured by either the performance-based or the self-reported measurements and there were ceiling effects on the questionnaires, important aspects of the patients' recovery and implications of the walking skill training program may not have been fully elucidated. Therefore, if clinicians develop and conduct interventions that address the patients' concerns, they may not be sufficiently evaluated by the measurements commonly used within this field. This calls for developing new assessment methods.

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PAPER I

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Functional improvements desired by patients before and in the first year after total hip arthroplasty

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Functional improvements desired by patients before and in the first year after total hip arthroplasty

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Abstract

Background: In the field of rehabilitation, patients are supposed to be experts on their own lives, but the patient's own desires in this respect are often not reported. Our objectives were to describe the patients' desires regarding functional improvements before and after total hip arthroplasty (THA).

Methods: Sixty-four patients, 34 women and 30 men, with a mean age of 65 years, were asked to describe in free text which physical functions they desired to improve. They were asked before surgery and at three and 12 months after surgery. Each response signified one desired improvement. The responses were coded according to the International Classification of Functioning, Disability and Health (ICF) to the 1st, 2nd and 3rd category levels. The frequency of the codes was calculated as a percentage of the total number of responses of all assessments times and in percentage of each time of assessment.

Results: A total of 333 responses were classified under Part 1 of the ICF, Functioning and Disability, and 88% of the responses fell into the Activities and Participation component. The numbers of responses classified into the Activities and Participation component were decreasing over time ($p < 0.001$). The categories of Walking (d450), Moving around (d455), and Recreation and leisure (d920) included more than half of the responses at all the assessment times. At three months after surgery, there was a trend that fewer responses were classified into the Recreation and leisure category, while more responses were classified into the category of Dressing (d540).

Conclusions: The number of functional improvements desired by the patients decreased during the first postoperative year, while the content of the desires before and one year after THA were rather consistent over time and mainly concerned with the ability to walk and participate in recreation and leisure activities. At three months, however, there was a tendency that the patients were more concerned about the immediate problems with putting on socks and shoes.

Keywords: Arthroplasty, Replacement, Hip, Rehabilitation, Desires, Functional improvement, ICF

Background

In the field of rehabilitation, patients are regarded to be experts on their own lives [1]. Many authors maintain that when rehabilitation interventions are being planned, the patients' own desires regarding functional improvement should be given more weight than is usual today [2]. This means that patients should have a strong say in defining which problems should be addressed during rehabilitation [3], and clinicians should take this into account and tailor the interventions to the patients' own desires to enable the patients to live meaningful lives [4]. Physiotherapy is a central element in rehabilitation after total hip arthroplasty (THA) for osteoarthritis (OA) [5]. As far as we know, what patients with THA actually want to obtain from physiotherapy is not reported.

Several studies have examined what patients expect from THA surgery. Mancuso et al. [6-8] found that the patients' preoperative expectations were to obtain pain relief and improve walking [6,7], and these expectations

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were fulfilled when the patients were asked four years later [8]. The results from other studies not directly examining expectations also suggest that pain relief is obtained and improved physical functioning are reached during the first year after surgery [9-14]. A qualitative study suggests that the patients expect to return to work and their previous level of physical functioning [15]. However, these studies do not especially address what patients expect from rehabilitation or physiotherapy after THA surgery.

Physiotherapy is aimed to improve and optimize physical functioning [16,17]. However, prior studies examining which improvements patients with THA expect with respect to physical functioning is mostly described in rather general terms, for example to improve walking [7]. Some may want to walk safely indoors, while others may want to do more demanding activities, such as skiing or hiking in the mountains, which they enjoyed before they became incapacitated [18]. Thus, we wanted to get a more detailed description of the activities the patients desired to improve during the first year after surgery, and we also wanted to examine whether their desires changed over time.

A way of assessing patients' desires is to ask the patients to describe in their own words what they wish to achieve. Such free text responses may be systematised by using the International Classification of Functioning, Disability and Health (ICF), developed by the World Health Organization (WHO). The ICF is a model and classification system that may contribute to broaden our understanding of the different ways in which chronic conditions can affect a patient's functioning [19]. The ICF model has two parts, each of which contains several components. Part 1 is Functioning and Disability, and includes the components Body Functions and Structures, and Activities and Participation (Figure 1). Part 2, Contextual Factors, also has two components: Environmental Factors and Personal Factors. In the present study we used the ICF as a tool to classify the free-text responses and describe what the patients with THA wished to improve during the first year after surgery.

The objective of this study was to describe the desires of a group of patients regarding improvements in physical functioning before they underwent THA and at three and 12 months after surgery.

Methods

Study design and participants

The present study is part of a study designed to examine recovery course the first year after surgery [14] and to examine whether participation in a physiotherapy programme starting three months after surgery influenced the recovery course [20]. The study had a longitudinal design, and the patients were asked to describe what they wanted to improve preoperatively and at three and 12 months postoperatively. Patients with hip OA were consecutively recruited the day before THA surgery and asked to participate in the study. They were recruited from two hospitals in the period from October 2008 to March 2010. The inclusion criteria were a diagnosis of primary hip OA and residence close to the hospital, i.e. within a radius of about 30 km, so as to make it easy for them to attend training sessions. They were excluded if they had OA in a knee or the contralateral hip that restricted walking, a neurological disease, dementia, heart disease, drug abuse and an inadequate ability to read and understand Norwegian. The study was carried out in compliance with the Helsinki Declaration, and

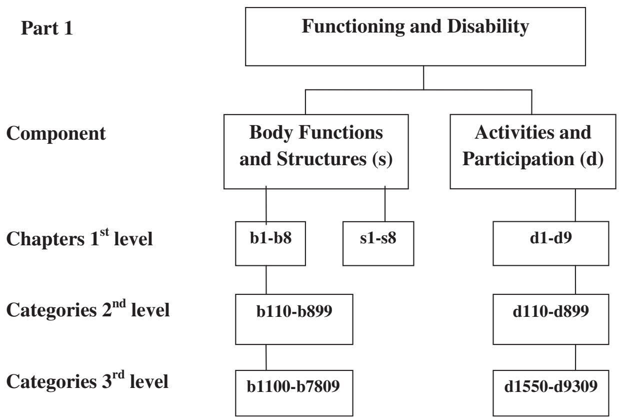

Figure 1 **Structure of part 1 of the international classification of functioning, disability and health (icf) applicable to patients after total hip arthroplasty.**

formal approval was given by the Regional Committee for Medical Research Ethics and Norwegian Social Science Data Services. Written consent for participation in the study was obtained from those who approved.

Personal characteristics

Before surgery the patients completed a questionnaire on age, sex, body weight, height, educational level, marital status, comorbidities, history of pain at night, prosthesis in the contralateral hip or knees, and their self-evaluated level of physical activity.

The patients' desires regarding improvements in physical functioning

The Patient-Specific Functional Scale (PSFS) has been developed to identify the kinds of problems a particular patient considers to be serious [21-23]. The patient responds in free text to the following question: "Today, are there any activities that you are unable to do or have difficulty with because of your problem?" In the present study we modified the PSFS question as follows "Which activities do you consider it important to improve?" As in the PSFS, the patients were asked to identify one to three activities. The patients were not shown their previous answers in the subsequent assessments at three and 12 months. Whether the question was understandable was tried out among some random patients at the hospital before the study started, and the question seemed understandable for the patients.

Analysis

All the patients' desires as expressed in free text were manually coded and classified according to the ICF. The responses were linked to the most closely related ICF categories according to the linking rules [24,25]. Each desire mentioned by each patient was considered to be one response. Thus, a patient who wished to improve three physical functions produced three responses. The desires were first classified under Part 1, Functioning and Disability, or Part 2, Contextual Factors. None of them were found to correspond to Contextual Factors. The desires were then classified under the Body Functions and Structures component or the Activities and Participation component. Then responses were linked first into chapter at 1st level, then category at the 2nd level and the 3rd level [19] (Figure 1). The classification process was completed by the first author in close cooperation with the third author, both being physiotherapists. When they were uncertain or they disagreed, the linking was discussed until consensus was reached. To make the coding process transparent [25], examples of how the responses were linked to the ICF are presented in Table 1. At each assessment, the total number of ICF-coded responses was counted and the proportion of responses in each category was calculated as a percentage of the total number of responses at the particular assessment time. To analyse whether the individuals changed their number of desires over time Friedman Test was used due to non-normally distributed data.

Table 1 Examples of patients' desires of functional improvements linked to the international classification of functioning, disability and health

2nd level classification	3rd level classifiacation	Patient's free text response
b455: Exercise tolerance functions	b4550: General physical endurance	"Improve endurance"
b730: Muscle power functions	b7301: Power of muscles in one limb	"Improve muscle strength in the limb"
b755: Involuntary movement reaction functions	No code at 3rd level	"Balance"
Walking (d450)	d4500: Walking	"To walk"
	d4501: Walking long distances	"Walking longer distances"
Moving around (d455)	d4551: Climbing	"Walking on stairs"
Dressing (d540)	d5402: Putting on socks and shoes	"Putting on sock and shoes"
		"Socks"
		"Tie shoes"
Caring for household objects (d650)	D6505: Taking care of plants and animals	"Gardening"
Recreation and leisure (d920)	d9201: Sport	"Skiing"
		"Bicycling"
		"Swimming"
		"Playing golf"
		"Playing tennis"
		"Playing badminton"
		"To participate in a training group"
	d9208: Other specified recreation and leisure activities	"Hiking in the mountain"
		"Go for long walks in the woods"
		"Go for walks a couple of hours"
		"Go for long walks with the dog"
		"Hunting"
		"Fishing"
		"Build a cottage"
		"Woodcutting"

Results

Participants

Before surgery, 128 patients who fulfilled the inclusion criteria were asked to participate. Thirty-six patients declined, leaving 92 to be assessed preoperatively. Twenty-four patients withdrew from the study at three months, and four withdrew before the 12-month assessments. In this study, we report the responses of the 64 patients who participated at all assessment times. The patients' mean age was 65 years, range 45–81, and the group included 34 women and 30 men (Table 2).

Overview of the patients' responses

A total of 333 free-text responses were received at the three assessment times, all of which were classified under the Functioning and Disability part of the ICF. Of these, 41 responses (12%) were classified into six different categories under Body Functions and Structures at the 2^{nd} level (Table 3), while 292 responses (88%) were classified into ten categories under Activities and Participation at the 2^{nd} level (Table 4). The total number of responses at each assessment time decreased during the year, from 145 responses before surgery to 109 at three months and 79 at 12 months.

Desired improvements of physical functioning

The results are shown in detail in Tables 3 and 4. Of the total responses at the different assessment times, 10% to 15% were classified under the component Body Functions and Structures, while 85% to 91% of the responses were classified into the component Activities and Participation. At the 2^{nd} level classification 42% to 47% of the responses were classified into the categories Walking (d450) and Moving around (d455) at the different time points. Over time, 13% to 25% of the responses were classified into the category Recreation and leisure (d920). At three months there was a tendency of fewer responses coded into the category Recreation and leisure (d920) and some increase of the responses classified into the Dressing (d540) category. At 12 months, 12 patients had no further desires and answered that everything was OK.

When comparing the responses of each individual at the different time points a change in what they wanted to improve from one time to another was seen for most of the patients. The different desires of improvement were distributed evenly across ages and among men and women. The number of desires within patients classified into the Body Functions and Structures component did not change over time ($p = 0.8$). There was a decrease in number of desires classified into the Activities and Participation component reported by the subjects from preoperative median (25%-75% percentiles) 2 (1–3), to three months 1 (1–2), and to 12 months after surgery 1 (0–1) ($p < 0.001$).

Table 2 Personal characteristics of the patients before total hip arthroplasty (n = 64)

Characteristics	n (%)	Mean (95% CI)
Age (y)		65 (64, 67)
Body mass index		27 (26, 28)
Women	34 (53)	
Educational level of >12 years	37 (58)	
Married/cohabiting	50 (78)	
Exeter prosthesis	47 (73)	
Spectron prosthesis	17 (27)	
Previous prosthesis hip or knee	19 (30)	
Pain at night	50 (78)	
Previous physical activity level (high/moderate)	45 (70)	
Comorbidity	20 (31)	
Physiotherapy within/during first 3 months	46 (71)	

Discussion

More than 85% of the patients' desires before and after THA were classified under the Activities and Participation component of the ICF. More than half of the total responses were classified into the categories of Walking, Moving around, and Recreation and leisure. The desires were rather consistent over time, but there was noticed some reduction of responses in the Recreation and leisure category and an increase into the Dressing category at three months after arthroplasty. The number of desires presented by each individual decreased during the first postoperative year.

Our finding that most of the functional improvement responses fell into the Activities and Participation component is in line with previous research on patients with different forms of non-surgical musculoskeletal disorders. In a large sample of PSFS responses from patients receiving physiotherapy for musculoskeletal disorders, Fairbairn et al. [26] found that most responses could be classified under the activity component of the ICF. Hobbs et al. [27] studied patients' free text responses to two questions on expectations before THA. One of the questions concerned what the patients felt they needed and the other what they wished to achieve. They found that only a few responses could be classified as Body Functions, and that the majority were classified under the Activities and Participation component. These questions about patients' needs and desires seem to be closely related to our question about patients' desires, which suggests that our preoperative results support their findings. In neither of the two studies, however, could any responses be classified at the third category level, so that our study provides a more detailed description of what patients wish to improve before and after surgery. Mancuso et al. [6,8] found that improvements in walking were expected by most of the patients preoperatively. Our results give a more detailed description about the patients' desire of walking, as the desires of walking and moving about also implied demanding

Table 3 No. (% of total) of responses classified into part 1, body functions and structures, of the international classification of functioning, disability and health

1st level classification (ICF chapters)	2nd level classification (ICF categories)	3rd level classification (ICF categories)	Before surgery no. (% of total 145)	3 months after surgery no. (% of total 109)	12 months after surgery no. (% of total 79)
b 1: Mental functions	Sleep functions (b134)	Quality of sleep (b1343)	2 (1.4)	0 (0)	0 (0)
b 4: Functions of cardiovascular and respiratory systems	Exercise tolerance functions (b455)	General physical endurance (b4550)	5 (3.4)	2 (1.8)	1 (1.3)
b 7: Neuromuscular and movement-related functions	Mobility of joint functions (b710)	Mobility of a single joint (b7100)	5 (3.4)	4 (3.7)	1 (1.3)
	Muscle power functions (b730)	Power of muscles in one limb (b7301)	0 (0)	2 (1.8)	2 (2.5)
	Involuntary movement reaction functions (b755)	No code at 3rd level	1 (0.7)	7 (6.4)	8 (10.1)
	Gait pattern function (b770)	No code at 3rd level	1 (0.7)	0 (0)	0 (0)
Total no. of responses of Body Functions and Structures			14 (9.6)	15 (13.7)	12 (15.2)

Differences in number of responses within subjects over time; $p = 0.8$.

activities such as sport activities and other leisure activities like hunting and fishing. These can be challenging desires to approach for the field of rehabilitation in general and for physiotherapists in particular.

The patients had a decreasing number of desires over time. Further, when looking at each patient's responses from one assessment to another we found that most of the patients presented new and different desires. This suggests that when improvements were reached in some activities, new desires of improvements within other activities may have appeared. At three months, desires tended to change from recreation and leisure activities to dressing, in particular to put on socks and shoes. This probably reflects the fact that the movement restrictions imposed by the surgeon, which included not allowing hip ROM to exceed 90° of hip flexion during the first three months, made it difficult for them to reach down far enough to put on socks and shoes. At 12 months, these patients no longer seemed to have difficulty with dressing and climbing stairs. However, just like before surgery many of the patients expressed a desire for further improvements classified into the recreation and leisure category. In a previous study of patients with hip and knee OA it was also found that return to recreational activities and no restriction in walking were among the issues of most concern to the patients [28]. The study was based on a questionnaire and only investigated patients' desires before surgery, while we found that the free text responses related to improvements in recreational and leisure activities were still present at 12 months after surgery. To our knowledge, this is the first study to show that the patients' desires before surgery remain relatively consistent during the first year after THA.

Questionnaires have been developed to assess therapeutic outcomes from a patient perspective. The Hip Dysfunction and Osteoarthritis Outcome Score (HOOS) [29] and the Harris Hip Score (HHS) [30] are frequently used for assessing outcome after THA. In these questionnaires pain is essential, together with physical functioning. Our question was related to functional improvements desired by the patients and explains why pain relief was not an adequate answer to our question. Both HOOS and HHS mainly address activities related to hip ROM and different forms of indoor everyday activities. We found that many of the issues of physical functioning relevant to the patients are not covered in the questionnaires, such as endurance, balance, and different leisure activities, like hiking in the woods, skiing and bicycling. In the HHS, there are two items out of ten about walking long distances and using public transport, and in the HOOS three items out of 40 that address shopping, running and performing heavy domestic duties. Thus, there is a discrepancy between what our patients wanted to achieve and what is captured by the questionnaires. In the categories under the Activities and Participation component, the questionnaires include many items related to daily activities such as rising up from the bed or a chair, putting on socks and shoes and walking short distances. According to our findings these items can be found relevant by the patients in the short term after surgery, but in less extent 12 months after surgery where the patients seem to focus on more demanding activities. As these particular questionnaires do not deal fully with concerns that patients may find important, it can be difficult to use these instruments when evaluating whether the goals of rehabilitation are reached.

The validity of the results depends on the quality of the process of linking the responses to the ICF. The linking recommendations have been followed [25]. In order to address a question about validity, we have chosen to make our coding process as transparent as possible in Table 1, according to the discussion of Fayed et al. [31]. Several

Table 4 No. (% of total) of responses classified to part 1, activities and participation, of the international classification of functioning, disability and health

1st level classification (ICF chapters)	2nd level classification (ICF categories)	3rd level classification (ICF categories)	Before surgery no. (% of total 145)	3 months after surgery no. (% of total 109)	12 months after surgery no. (% of total 79)
d 4: Mobility	Changing basic body position (d410)	Lying down (d4100)	3 (2.1)	0 (0)	3 (3.8)
		Squatting (d4101)	0 (0)	3 (2.8)	1 (1.3)
		Sitting (d4103)	4 (2.8)	2 (1.8)	0 (0)
		Bending (d4105)	3 (2.1)	3 (2.8)	2 (2.5)
	Maintaining body position (d415)	Maintaining a kneeling position (d4152)	1 (0.7)	0 (0)	0 (0)
		Maintaining a sitting position (d4153)	1 (0.7)	0 (0)	1 (1.3)
		Maintaining a standing position (d4154)	1 (0.7)	1 (0.9)	0 (0)
	Walking (d450)	Walking (d4500)	22 (15.2)	8 (7.3)	6 (7.6)
		Walking long distances (d4501)	20 (13.8)	22 (20.2)	17 (21.5)
		Walking on different surfaces (d4502)	3 (2.1)	0 (0)	0 (0)
	Moving around (d455)	Crawling (d4550)	0 (0)	1 (0.9)	0 (0)
		Climbing (d4551)	18 (12.4)	17 (15.6)	6 (7.6)
		Running (d4552)	5 (3.4)	1 (0.9)	4 (5.1)
d 5: Self-care	Dressing (d540)	Dressing (d5400)	1 (0.7)	0 (0)	0 (0)
		Putting on socks and shoes (d5402)	9 (6.2)	18 (16.5)	5 (6.3)
d 6: Domestic life	Household tasks (d640)	Cleaning (d6402)	0 (0)	2 (1.8)	1 (1.3)
	Caring for household objects (d650)	Taking care of plants and animals (d6505)	3 (2.1)	2 (1.8)	1 (1.3)
d 8: Major life areas	Work and employment (d845)	Keeping a job (d845)	1 (0.7)	0 (0)	0 (0)
d 9: Community, social and civic life	Recreation and leisure (d920)	Sport (d9201)	10 (6.9)	5 (4.6)	16 (20.3)
		Other specified recreation and leisure activities (d9208)	26 (17.9)	9 (8.3)	4 (5.1)
Total no. of responses of Activities and Participation			131 (90.5)	94 (86.2)	67 (85.0)

Differences in number of responses within subjects over time; $p < 0.001$.

authors have used two independent coders to minimize assessor bias. However, a high reliability between coders has been reported [25,27,32]. In these studies, the reliability was not examined at the 3rd category level. We had few doubts about how to code before we reached to the 3rd level. Especially to the category Recreation and leisure it was often challenging to link the responses at the 3rd level because the codes did not have a high enough level of detail. According to the linking rules responses should not be linked to the code Other specified recreation and leisure activities (d9208). Nevertheless, we did not find any other suitable category to classify responses such as "hiking", "go for walks in the woods", "hunting", and "fishing". Hence, we chose to use this code. Further, it seemed that the patients had no difficulties in understanding the question raised in the modified PSFS, because they did not ask for explanations, and they gave clear and concise responses to the question.

Another important question to address is whether the patients' responses are biased by the participation in a training programme aimed to improve walking starting three months after surgery and lasting for about two months. Half of the patients participated in this programme. When we examined the responses of the two groups separately, the percentage of responses coded as Body Functions and Activities and Participation, as well as in the categories of Walking, Moving around, and Recreation and leisure, remained approximately unchanged. Taken together, we think our coding is adequately performed at the component and first two levels, but it can be less valid at the 3rd level.

Another important question is whether our results can be generalised to other THA patient populations. The patients in this study, who had been consecutively recruited to participate in a study investigating the effect of a training programme, had a mean age four years younger than the mean age of THA patients in Norway, they were non-obese, higher educated than the Norwegian population, married, and had a moderate or high level of physical activity before surgery. Thus, our group of patients may have been to some extent selected from among a fairly healthy, physically active population. This may also explain that they wanted to be able to perform rather demanding activities. However, increasing numbers of those undergoing arthroplasty today seem to be relatively healthy, and, as our study points out, many of them wish to lead an active life.

Conclusions

Linking patients' responses to the ICF showed a decrease in number of desires over time, and the most frequent functional improvements desired by the patients both before and one year after THA were walking, moving around and participating in rather demanding recreation and leisure activities. In the early postoperative phase, on the other hand, the described pattern of the patients' desires changed and they were more concerned about improving temporary limitations in physical functioning. The improvements desired by the patients were not covered in the most widely used disease-specific questionnaires.

Abbreviations

HHS: Harris hip score; HOOS: Hip dysfunction and osteoarthritis outcome score; ICF: International classification of functioning, disability and health; OA: Osteoarthritis; PSFS: Patient-specific functional scale; THA: Total hip arthroplasty.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

KEH, AE and AMM designed the study. MDH and AGK collected the data. KEH analyzed and drafted the manuscript with regular feedback from AMM. All authors read and approved the final manuscript.

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II

PAPER II

Kristi Elisabeth Heiberg, Arne Ekeland, Vigdis Bruun-Olsen, Anne Marit Mengshoel.

Recovery and prediction of physical functioning outcomes during the first year after total hip arthroplasty

Archives of Physical Medicine and Rehabilitation. 2013;94(7):1352-9.

III

PAPER III

Kristi Elisabeth Heiberg, Vigdis Bruun-Olsen, Arne Ekeland, Anne Marit Mengshoel.

Effect of a walking skill training program in patients who have undergone total hip arthroplasty: Followup one year after surgery

Arthritis Care & Research (Hoboken). 2012;64:415-423.

APPENDIX

Tillit til egen aktivitetsmestring

Aktivitetsområder:	Svært usikker ↓										Svært sikker ↓
Hvor sikker/trygg er du på at du i dag kan:	0	1	2	3	4	5	6	7	8	9	10
bøye deg ned og plukke opp en gjenstand fra gulvet											
stå på kne og luke et blomsterbed											
sitte på huk											
gå i trapp 2 etasjer uten å holde i gelenderet											
rekke og gå over fotgjengerfeltet på grønt lys											
gå å handle i en folksom gate											
gå 2 km tur i skogen (ulendt terreng) i normalt tempo											
unngå å falle ved aktiviteter innendørs											
unngå å falle ved aktiviteter utendørs											
leve et så aktivt liv som du ønsker											

Hvilke aktiviteter er viktige for deg å forbedre?

I venstre kolonne skriver du den eller de aktivitetene du ønsker å bli bedre i. I høyre kolonne angir du grad av vanskelighet du har med å utføre aktiviteten.

Angi det sifferet på skalaen som svarer til hvor vanskelig du synes det er å utføre aktiviteten!	
Aktivitet:	**Grad av vanskelighet**
1	
2	
2	
Grad av vanskelighet (merk retning på skalaen):	
0 1 2 3 4 5 6 7 8 9 10	
Klarer ikke	Klarer uten vansker

Spørreskjema for hoftepasienter (HOOS)

Sett kryss ved det alternativet du mener stemmer best (ett alternativ for hvert spørsmål). Dersom du er usikker, kryss allikevel av ved det alternativet som føles mest riktig.

Symptomer

Tenk på **hoftesymptomene** og vanskelighetene du har hatt i løpet av **den siste uken** når du besvarer disse spørsmålene.

S1. Har du kjent knirking i hoften, hørt klikking eller andre lyder fra hoften?

Aldri	Sjelden	Av og til	Ofte	Alltid
☐	☐	☐	☐	☐

S2. Vanskeligheter med å føre bena langt fra hverandre?

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

S3. Vanskeligheter med å skritte helt ut når du går?

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

Stivhet

De følgende spørsmålene omhandler **leddstivhet.** Leddstivhet innebærer vanskeligheter med å komme i gang eller øket motstand ved bevegelser.

Angi den grad av hofteleddstivhet du har kjent i løpet av den siste uken.

S4. Hvor stiv har hoften din vært når du akkurat har våknet om morgenen?

Ikke noe	Litt	Moderat	Veldig	Ekstremt
☐	☐	☐	☐	☐

S5. Hvor stiv har hoften din vært etter å ha sittet eller ligget og hvilt deg **senere på dagen**?

Ikke noe	Litt	Moderat	Veldig	Ekstremt
☐	☐	☐	☐	☐

Smerte

P1. Hvor ofte har du hoftesmerter?

Aldri	Hver måned	Hver uke	Hver dag	Alltid
☐	☐	☐	☐	☐

Følgende spørsmål omhandler hoftesmerten du eventuelt har opplevd den siste uken.
Angi graden av smerte du har kjent i forbindelse med **følgende aktiviteter:**

P2. Strekke hoften helt ut

Ingen	Litt	Moderat	Sterk	Svært sterk
☐	☐	☐	☐	☐

(**Angi grad av smerte** forts.)

P3. Bøye hoften helt

Ingen	Litt	Moderat	Sterk	Svært sterk
☐	☐	☐	☐	☐

P4. Gå på jevnt underlag

Ingen	Litt	Moderat	Sterk	Svært sterk
☐	☐	☐	☐	☐

P5. Gå opp eller ned trapper

Ingen	Litt	Moderat	Sterk	Svært sterk
☐	☐	☐	☐	☐

P6. Til sengs om natten (smerte som forstyrrer søvnen)

Ingen	Litt	Moderat	Sterk	Svært sterk
☐	☐	☐	☐	☐

P7. Sittende eller liggende

Ingen	Litt	Moderat	Sterk	Svært sterk
☐	☐	☐	☐	☐

P8. Stående

Ingen	Litt	Moderat	Sterk	Svært sterk
☐	☐	☐	☐	☐

P9. Gå på hardt underlag, f. eks. asfalt eller betong

Ingen	Litt	Moderat	Sterk	Svært sterk
☐	☐	☐	☐	☐

P10. Gå på ujevnt underlag

Ingen	Litt	Moderat	Sterk	Svært sterk
☐	☐	☐	☐	☐

Fysisk funksjon

Følgende spørsmål omhandler din fysiske funksjon. **Angi graden av vanskeligheter** du har opplevd i løpet av den **siste uken** ved følgende **aktiviteter** på grunn av dine hofteproblemer.

A1. Gå ned trapper

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A2. Gå opp trapper

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A3. Reise deg opp fra sittende

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

(**Angi grad av vanskeligheter** forts.)

A4. Stå stille

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A5. Bøye deg ned mot gulvet, f. eks. for å plukke opp en gjenstand

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A6. Gå på jevnt underlag

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A7. Komme inn og ut av bilen

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A8. Handle / gjøre innkjøp

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A9. Ta på sokker / strømper

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A10. Reise seg opp fra sengen

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A11. Ta av sokker / strømper

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A12. Ligge i sengen (snu deg rundt, holde hoften lenge i samme stilling)

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A13. Stige inn og ut av badekar / dusj

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A14. Sitte

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A15. Sette deg og reise deg fra toalettet

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

(**Angi grad av vanskeligheter** forts.)

A16. Gjøre tungt husarbeid (måke snø, vaske gulv, støvsuge etc)

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

A17. Gjøre lett husarbeid (lage mat, tørke støv etc)

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

Funksjon, idrett og fritid

Følgende spørsmål angår dine aktivitetsbegrensninger. **Angi grad av vanskeligheter** du har opplevd i løpet av den **siste uken** ved følgende **aktiviteter** på grunn av dine hofteplager.

SP1. Sitte på huk

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

SP2. Løpe

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

SP3. Snu om / vende på belastet ben

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

SP4. Gå på ujevnt underlag

Ingen	Litt	Moderate	Store	Svært store
☐	☐	☐	☐	☐

Livskvalitet

Q1. Hvor ofte gjør ditt hofteproblem seg bemerket?

Aldri	Hver måned	Hver uke	Hver dag	Alltid
☐	☐	☐	☐	☐

Q2. Har du forandret livsstil for å unngå å overbelaste hoften?

Ikke	Litt	Moderat	I stor grad	Totalt
☐	☐	☐	☐	☐

Q3. I hvor stor grad kan du stole på hoften din?

Fullstendig	I stor grad	Middels	Noe	Ikke
☐	☐	☐	☐	☐

Q4. Generelt sett, hvor store problemer har du med hoften?

Ingen	Små	Moderate	Store	Svært store
☐	☐	☐	☐	☐

Takk for at du tok deg tid til å fylle ut dette skjemaet!

Treningsskjema

	Ingen aktivitet	Egenaktivitet (Antall minutter)		Hos fysioterapeut					
				Trening på egenhånd			Trening under veiledning		
Uke 1		Hjemmeøvelser	Tur, (f.eks gå, sykle)	Styrketrening med apparater	Øvelser på benk i liggende eller sittende	Øvelser i stående	Styrketrening med apparater	Øvelser på benk i liggende eller sittende	Øvelser i stående
mandag									
tirsdag									
onsdag									
torsdag									
fredag									
lørdag									
søndag									

ERRATA

On page 5, under Materials and Methods, line 6:

….control group (n = **33**)…

On Page 52, line 14:

…., but the **four** items included….

In Paper III, page 419, first column line 8:

The word “to” should be replaced by the word “by”; “…increased their walking distance by ≥50 meters…”, and also in the last line the word “to” should be replaced by the word “by”; “…..increased their walking distance by ≥50 meters at posttest…”