Functional decline after a hip fracture

Long-term trajectories and the impact of orthogeriatric care and of fracture type

Thesis by

Shams Dakhil

Department of Geriatric Medicine

Institute of Clinical Medicine

Faculty of Medicine

University of Oslo

2023

Series of dissertations submitted to the
Faculty of Medicine, University of Oslo

ISBN 978-82-348-0317-8

Cover: UiO.
Print production: Graphic center, University of Oslo.

Table of contents

Acknowledgements

The research presented in this thesis was carried out at the Department of Geriatric Medicine, Institute of Clinical Medicine, Oslo University Hospital and the University of Oslo. This research was funded by the Medical Research Program at the University of Oslo.

I would like to express my gratitude towards the participants and the caretakers/next of kin for participating in the original studies, upon which this thesis is based on. I also want to thank the staff at the Geriatric Department at Oslo University Hospital and St. Olavs Hospital, Trondheim University Hospital for assisting in data collection. Thank you to Ingvild Saltvedt, Olav Sletvold, Anders Prestmo in Trondheim, and Torgeir Bruun Wyller and Leiv Otto Watne in Oslo for planning and conducting both studies, and for planning ahead for them to be merged.

To my supervisors, Leiv Otto and Torgeir, I am deeply grateful. Leiv Otto, my principal supervisor, thank you for your continuous support, empathy, enthusiasm, quick replies, wit and your amazing ability to always find solutions to minor and major problems. Torgeir, my co-supervisor, thank you for sharing all your wisdom, always being available and for your support. I would also like to extend my gratitude to both of you for sharing your knowledge in geriatrics with me and for all you have taught me both clinically and in research. Thank you for giving me the opportunity to become both a researcher and a clinician within the field of geriatrics; you are both truly inspiring!

To all co-authors, I would like to extend a big thank you for all your valuable contributions to the manuscripts and the time you have taken to share your extensive knowledge with me. I feel truly privileged to have worked with such knowledgeable and kind people. I want to, especially, express my gratitude to Kristin, who supervised and supported me all through the process of writing the second manuscript. The process was easier and much more enjoyable with your guidance and support!

Thank you to all my colleagues at «Loftet» for making a great and warm atmosphere, in which I always felt welcome and always learned a lot. Especially, Nathalie, who have grown to not only be a colleague, but also a dear friend of mine. Thank you for your ongoing support, kind words and being one of my closest confidants. Working with you is a privilege!

Finally, a big thank you to my family and friends, who always stay by my side, support me and enrich my life. To my mother and father, who always believed I could do anything and encouraged me in all my academic endeavors, in addition to showering me with love and support. To my sisters and best friends, Mays, Sarah and Silje, for always cheering me on, and for having the utmost belief in me – even at the times when I could not believe in myself. And to Thorbjørn, my wonderful soon-to-be husband, thank you for all your support, love and patience. I love you all.

Summary in English

Background

A hip fracture is one of the most common fractures in older adults, and is a serious and dramatic event, often with debilitating consequences such as loss of function and increased dependency. Patients suffering from a hip fracture due to low-energy trauma are often frail and have multiple comorbidities, often making them more susceptible for adverse outcomes. Furthermore, a decline in Activities of Daily Living (ADL) preceding the fracture is not uncommon in this patient population. A significant number of these patients do not regain their pre-fracture function, and the subsequent decline in ADL function is associated with reduced quality of life and an increase in nursing home admissions. This, in turn, might require more socioeconomic and public health care services.

Aims

The aims of this thesis were to 1) evaluate the effect of an orthogeriatric model delivered in acute geriatric wards in Norway on instrumental ADL (iADL) and personal ADL (pADL) in hip fracture patients, 2) investigate different trajectories of ADL after a hip fracture and associated factors for belonging to such groups, and 3) investigate differences between intracapsular and extracapsular hip fracture patients.

Methods

This study is based on two randomized controlled trials, conducted in Norway, which aimed to investigate the effect of orthogeriatric care on hip fracture patients. Patients were randomized either to a geriatric ward where they received comprehensive geriatric care (CGC) or to the orthopedic ward where they received usual care. The operative and anesthesiologic procedures were similar in both groups and assessments were carried out at baseline, four- and twelve-months postoperatively. These trials were planned in concert for future pooling of data, and is the basis for this thesis. The goal was to combine the two trials to make a larger and more heterogeneous database on hip fracture patients, for the opportunity to make more precise estimates on outcomes and increase generalizability. The combined database included 726 hip fracture patients, and all available outcomes that were similar or identical in the two trials were merged and included in the database.

Main results

The group of patients that received CGC had significantly better iADL scores at both four-

and twelve-months follow-up, and significantly better pADL scores at four months follow up compared to the control group. When excluding the patients admitted from a nursing home, the effect of the intervention became stronger.

We found four different groups of patients following distinct trajectories of function for both iADL and pADL. No group showed functional recovery the first twelve months after surgery. Especially, there was one group for both iADL and pADL, which had relatively high baseline ADL scores, but exhibited a steep decline in function the first four months after surgery. Younger age, an ASA score of 1 or 2 and lower CDR scores at baseline were associated with belonging to groups with better trajectories.

Patients with an intracapsular fracture have better mobility and ADL function initially after a hip fracture, but these differences do not persist at one year follow-up, in which both groups are similar in regards to cognitive, physical and ADL function. There were no differences between groups in regards to baseline characteristics.

Conclusions

CGC has a positive effect on both iADL and pADL in hip fracture patients up to one year after hip fracture surgery. The effect is stronger in home-dwelling patients.

There are different groups of hip fracture patients exhibiting different patterns of functional recovery after a hip fracture. Similar for all groups found in this study, was that no group had any functional recovery the first year after surgery. This study also uncovered a clinically interesting group for both iADL and pADL, which were relatively healthy and had relatively good pre-fracture function, but had a vast functional decline one year postoperatively. This group should be studied in future research to uncover the potential for rehabilitation.

Patients with an intracapsular hip fracture have a faster initial rehabilitation after surgery, compared to patients with an extracapsular hip fracture. The two groups of patients with different hip fractures have similar baseline characteristics.

Norsk sammendrag

Bakgrunn

Et hoftebrudd er et av de vanligste bruddene hos eldre personer, og er en alvorlig og dramatisk hendelse, ofte med invalidiserende konsekvenser som funksjonstap og økt avhengighet. Pasienter som rammes av et hoftebrudd på grunn av et lavenergitraumer er ofte skrøpelige og har flere komorbiditeter, noe som gjør dem mer utsatt for uønskede utfall. En nedgang i dagliglivets aktiviteter (ADL) før bruddet er ikke uvanlig i denne pasientpopulasjonen. Et betydelig antall av disse pasientene gjenvinner ikke funksjonen de hadde før bruddet, og den påfølgende nedgangen i ADL-funksjon er assosiert med redusert livskvalitet og økt antall innleggelser på sykehjem. Dette krever flere sosioøkonomiske og offentlige ressurser.

Mål

Målet med denne studien var å 1) evaluere effekten av en ortogeriatrisk modell levert på akuttgeriatriske avdelinger i Norge på instrumentelle ADL (iADL) og personlig ADL (pADL) hos hoftebruddpasienter, 2) undersøke ulike forløp for ADL etter et hoftebrudd og assosierte faktorer for tilhørighet i slike grupper, og 3) undersøke forskjeller mellom intrakapsulære og ekstrakapsulære hoftebruddpasienter.

Metoder

Denne studien er basert på to randomiserte kontrollerte studier, utført i Norge, som hadde som mål å undersøke effekten av ortogeriatrisk behandling på hoftebruddpasienter. Pasientene ble randomisert enten til en geriatrisk avdeling hvor de fikk ortogeriatrisk behandling (CGC) eller til ortopedisk avdeling hvor de fikk vanlig behandling. De operative og anestesiologiske prosedyrene var like i begge grupper, og vurderinger ble utført ved innleggelse, samt fire og tolv måneder postoperativt. Studiene ble planlagt i fellesskap for å kunne slå dataene sammen i fremtiden, og danner grunnlaget for denne studien. Målet var å kombinere de to studiene for å lage en større og mer heterogen database på hoftebruddpasienter, og dermed gjøre mer presise estimater på utfall, samt øke generaliserbarheten. Den kombinerte databasen inkluderte 726 hoftebruddpasienter, og alle tilgjengelige utfall som var like eller identiske i de to studiene ble slått sammen og inkludert i databasen.

Hovedresultater

Pasientene som fikk CGC hadde signifikant bedre iADL-skår ved både fire- og tolvmåneders

oppfølging, og signifikant bedre pADL-skår ved fire måneders oppfølging sammenlignet med kontrollgruppen. Når sykehjemspasienter ble ekskludert fra analysene ble effekten av intervensjonen sterkere.
Vi fant fire ulike grupper av pasienter som fulgte hver sine forløp for ADL-funksjon, for både iADL og pADL. Ingen av gruppene gjenvant sin pre-fraktur ADL-funksjon i løpet av første tolv månedene etter operasjonen. Spesielt var det én gruppe for både iADL og pADL, som hadde relativt høye ADL-skårer ved innleggelse, men som viste en kraftig nedgang i funksjon de første fire månedene etter operasjonen. Yngre alder, en ASA-skår på 1 eller 2 og lavere CDR-skår ved innleggelse var assosiert med å tilhøre bedre ADL-forløp.
Pasienter med intrakapsulære hoftebrudd har bedre mobilitet og ADL-funksjon initielt etter et hoftebrudd. Disse forskjellene vedvarer derimot ikke ved ett års oppfølging, der begge gruppene er like med hensyn til kognitiv-, fysisk- og ADL-funksjon. Det var ingen forskjeller mellom gruppene ved innleggelse.

Konklusjoner
CGC har en positiv effekt på både iADL og pADL hos hoftebruddpasienter inntil ett år etter operasjon for hoftebrudd. Effekten er sterkere hos hjemmeboende pasienter.
Vi fant ulike grupper av hoftebruddpasienter, som følger forskjellige forløp for ADL-funksjon etter et hoftebrudd. Tilsvarende for alle gruppene funnet i denne studien, var at ingen av gruppene gjenvant den ADL-funksjonen de hadde før hoftebruddet. Det ble også avdekt en klinisk interessant gruppe for både iADL og pADL, som var relativt friske og hadde relativt god ADL-funksjon før hoftebruddet, men som hadde en enorm funksjonsnedgang første året etter hoftebruddsoperasjonen. Denne gruppen bør studeres mer i fremtidig forskning for å avdekke potensialet for rehabilitering.
Pasienter med intrakapsulære hoftebrudd har en raskere rehabilitering etter operasjon initielt, sammenlignet med pasienter med ekstrakapsulære hoftebrudd. De to gruppene av pasienter med forskjellige hoftebrudd har lignende karakteristika ved innleggelse.

Abbreviations

ASA – American Society of Anesthesiologists

BADL – Barthel ADL Index

CCI – Charlson Comorbidity Index

CDR – Clinical Dementia Rating Scale

CGA – Comprehensive Geriatric Assessment

CGC - Comprehensive Geriatric Care

CI – Confidence interval

CSDD – Cornell Scale for Depression in Dementia

GDS-15 – Geriatric Depression Scale 15

HA – Hemiarthroplasty

iADL – Instrumental Activities of Daily Living

LOS – Length of Hospital Stay

MMSE – Mini Mental Status Examination

NEADL – Nottingham Extended ADL

OC – Orthopedic Care

pADL – Personal Activities of Daily Living

SPPB – Short Physical Performance Battery

THA – Total Hip Arthroplasty

TOOHIP – The OslO and Trondheim Hip Fracture Trial

List of papers

I. **Orthogeriatrics prevents functional decline in hip fracture patients: report from two randomized controlled trials.** Dakhil, S, Thingstad, P, Frihagen, F, Johnsen, LG, Lydersen, S, Skovlund, E, Wyller, TB, Sletvold, O, Saltvedt, I, Watne, LO. BMC Geriatrics 2021 Vol. 21 Issue 1: 208

II. **Longitudinal trajectories of functional recovery after hip frature.** Dakhil, S, Saltvedt, I, Benth, JS, Thingstad, P, Watne, LO, Wyller, TB, Helbostad, JL, Frihagen, F, Johnsen, LG, Taraldsen, K. PLoS ONE 2023 Vol. 18 Issue 3: e0283551.

III. **Patients with extracapsular hip fractures compared to patients with intracapsular hip fractures - a secondary analysis cohort study rebuking common orthopedic perception.** Dakhil, S, Djuv, A, Saltvedt, I, Wyller, TB, Frihagen, F, Johnsen, LG, Taraldsen, K, Helbostad, JL, Watne, LO, Paulsen, A.
Manuscript submitted to journal

1. Introduction

1.1 Hip fractures

1.1.1 Epidemiology of a hip fracture

A hip fracture is a common fracture in adults over the age of 50 years (1-4). This is one of the most debilitating conditions in older adults, often causing loss of function and dependency. Hip fractures are also referred to as fragility-fractures. The patients are often frail, with multiple comorbidities and polypharmacy, and therefore are more likely to sustain a fracture from a low-energy trauma, such as falling from standing height. Common comorbidities are dementia, sarcopenia and osteoporosis; with delirium superimposed on dementia in conjunction with the hip fracture being a common complication (5).

The age-adjusted incidence of hip fractures has increased steadily over the last decades, and is now decreasing (6). Still, the number of hip fractures is expected to increase due to the rapidly aging population worldwide, as well as increase in life-expectancy, and it’s estimated to reach 4.5 million by year 2050 (6). Hip fracture rates are generally high worldwide, with intercontinental variability. Scandinavian countries have the highest hip fracture rates, African countries have the lowest (7, 8). In general, the majority of hip fracture patients are women (70-75%) (9) and in Norway the mean age is 82 years; 83 years for women and 81 years for men (10).

There are several risk factors associated with a hip fracture, with higher age being among the important ones. An increase in age is associated with lower bone mass density and osteoporosis, resulting in higher risk of fractures when falling. Frailty is also more common with higher age, defined as increased vulnerability due to age-associated decline in reserve and function of multiple physiologic systems (11). Consequently, this will result in less robustness when experiencing an external stressor, such as a fall and subsequent hip fracture, increasing the risk of complications (12, 13).

Another apparent risk factor for a hip fracture is a fall. A hip fracture occurring as a consequence of a fall from standing height, is called a low-energy trauma fracture. It is estimated that about one third of home-dwelling older adults, aged 65 years or older, will fall, with about half of these patients experiencing multiple falls (14). Comorbidity, and by extension polypharmacy, are important risk factors for falling. This can be due to either the symptoms of the disorders causing falls, or due to side-effects of the medications used for the disorders. Neurological disorders that affect balance or muscle strength and cardiovascular disorders that cause arrhythmias are examples of such conditions. Cognitive impairment is also a risk factor for falls, due to impairment in executive functions and behavioral disturbances (15, 16). Furthermore, impaired vision, excess alcohol consumption and weather conditions (such as icy roads) can increase risk of falling.

Gender and ethnicity also impose important risk factors, as there are substantial differences between different ethnicities and genders when it comes to incidence of hip fracture, but also outcomes (9). Approximately 18% of women and 6% of men will experience a hip fracture (6). It is reported that men that suffer from a hip fracture are younger and have more comorbidities than women (9). Caucasian women have an increased risk of hip fracture, while the risk is lower in African women (7). Differences in outcomes based on ethnicity and gender will be presented in section 1.1.3.

1.1.2 Different hip fractures

Hip fractures, also named proximal fractures of the femur, are fractures occurring in the region between the subcapital region (the region just below the femoral head) and 5 cm below the lesser trochanter. They include two main types; the intracapsular hip fractures and the extracapsular hip fractures. These are classified based on the anatomic position of the fracture line, see Figure 1. Approximately 60% of hip fractures are intracapsular (17), and approximately 40% of hip fractures are extracapsular; of which 90% are trochanteric and 10% are subtrochanteric (18).

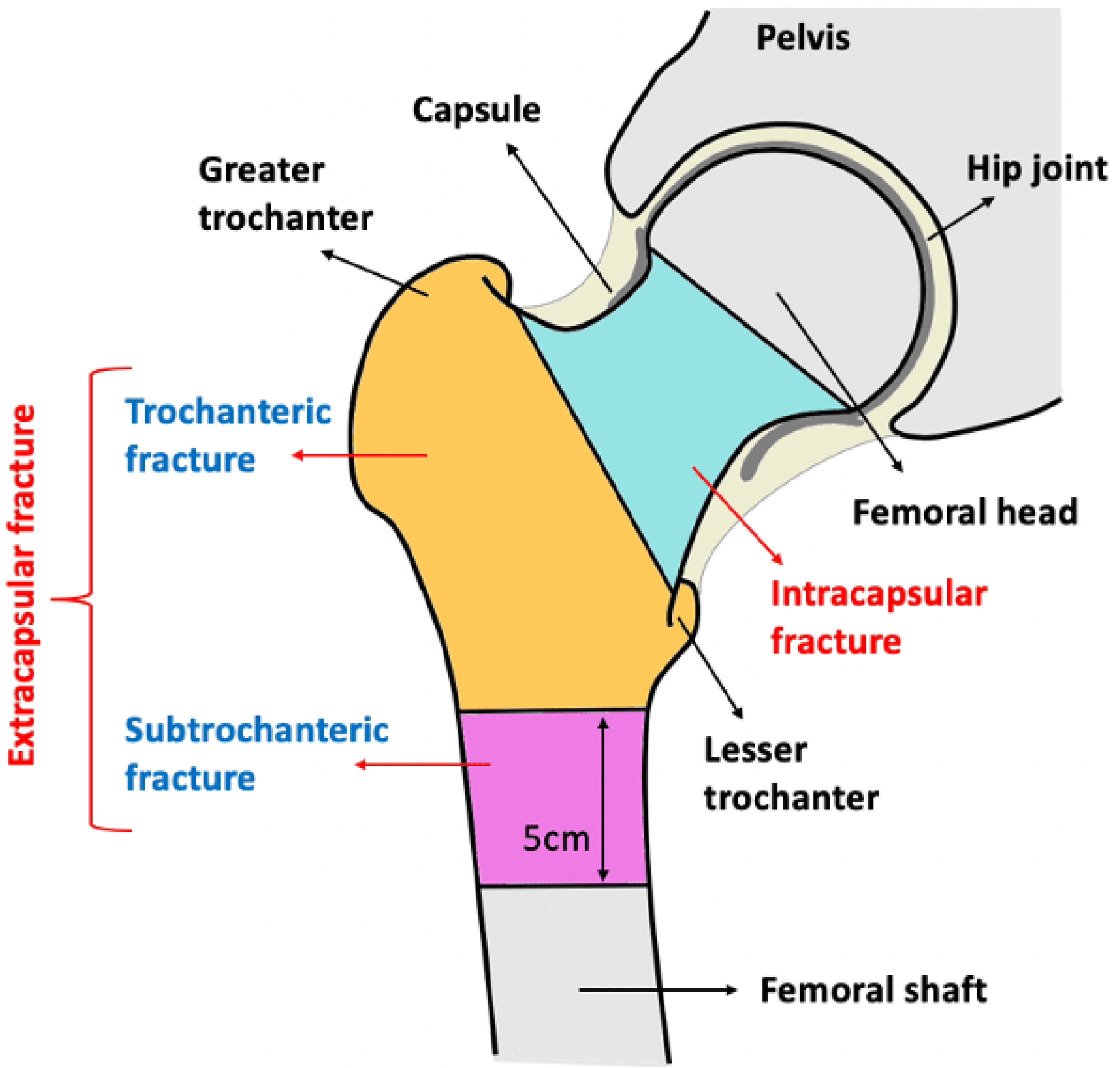

Figure 1 Anatomy of the proximal femur and the location of the hip fracture type (figure not modified, license https://creativecommons.org/licenses/by-nc/4.0/) (19).

Intracapsular hip fractures are hip fractures that occur inside the ligamentous hip joint capsule, and are also commonly named fractures of the femoral neck. These fractures can be further classified based on fracture morphology. Using the Garden classification system these fractures can be classified based on fracture morphology into non-displaced fractures (Grade I and II) or displaced fractures (Grade III and IV) (19), see Figure 2. Fracture morphology corresponds with prognosis, in which more displaced fractures have a higher likelihood of compromising the blood supply to the femoral head, which might lead to complications such as avascular necrosis (17). Furthermore, fracture morphology will often also dictate the surgical treatment. In general, arthroplasty is mainly used for intracapsular fractures, while internal fixation is used for special indications, such as in younger patients or in minimally displaced fractures (20-22).

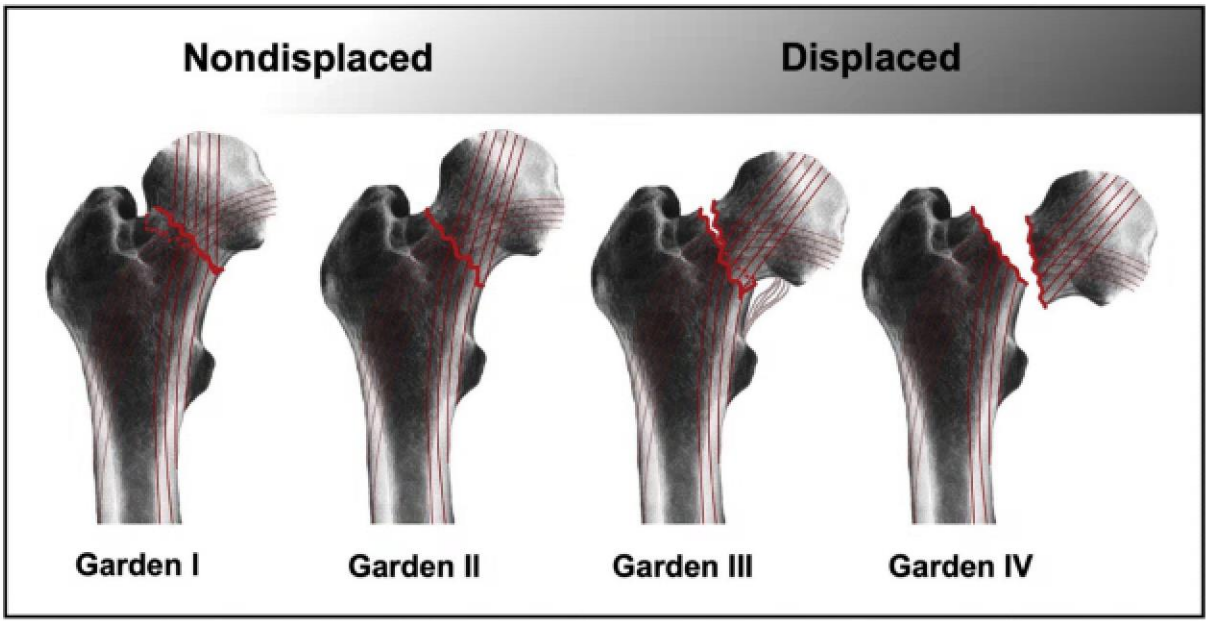

Figure 2 Garden classification of intracapsular hip fractures (figure not modified, license: http://creativecommons.org/licenses/by/4.0/) (23).

Extracapsular hip fractures comprise of the hip fractures that occur in the trochanteric and the subtrochanteric (the 5 cm below the lesser trochanteric) regions of the femoral bone, and are outside the capsule (Figure 1). The trochanteric fractures can be either stable or unstable (18), whilst the subtrochanteric fractures are often unstable due to the multiple deforming forces imposed on the fracture fragments by the muscles attached to the femoral bone (24). The preferred surgical method for extracapsular fractures is closed, or occasionally open, reduction followed by either an intramedullary nail or a sliding hip screw (25-28).

1.1.3 Consequences of a hip fracture

A hip fracture has substantial short- and long-term consequences for the patients sustaining them. Among them are mortality, delirium, reduced mobility, increased dependency in personal Activities of Daily Living (pADL) and instrumental ADL (iADL), change in place of residence and reduced quality of life.

The one-year mortality rate after a hip fracture is 20-25%, in which the patients with an extracapsular hip fracture have been reported to have higher mortality than intracapsular fractures (5, 29). This elevated mortality rate is highest in the days and weeks after a hip fracture, but remains elevated for years in hip fracture patients compared to home-dwelling older adults that did not suffer from a hip fracture (30). When comparing genders, men have a greater risk of mortality compared to women (30, 31). Comorbidity has been shown to affect mortality as well, with congestive heart failure, chronic obstructive pulmonary disease and dementia being among the most important ones increasing the mortality rate (32).

Comorbidity is also increased in patients after a hip fracture. Among complications after a hip fracture urinary tract infections, lower limb embolism and malnutrition are most common, with women more likely to experience these than men (33). Another important peri-operative complication is delirium, in both patients with and without dementia (34).
Pulmonary embolisms, infectious complications and heart failure are among the postoperative events that can lead to increased mortality (31). Furthermore, comorbidity before the fracture is a predictor for both mortality and mobility postoperatively (35).

A large proportion of hip fracture patients have cognitive impairment. In Norway approximately 50% of hip fracture patients suffer from dementia at the time of fracture (5), and delirium is a common complication in this population with a reported six-fold increase in probability of delirium with pre-existing dementia (34). Dementia is a chronic and progressive neurodegenerative disease, however, several studies have shown an association with delirium and worse long-term cognitive impairment; predicting dementia in cognitively unimpaired patients, and accelerating dementia in cognitively impaired patients (36, 37).

A hip fracture will affect the patient's mobility, both short- and long-term. Initially the mobility will be affected due to the fracture and loss of stability in the limb. In addition, pain as a result from the fracture will also impair mobility. Depending on the anatomical site of the hip fracture, more bleeding and soft tissue affection can be expected in extracapsular fractures (38), which will result in more pain. Surgical procedure also impact mobility. Intracapsular fractures are usually treated with arthroplasties, while extracapsular fractures are usually treated with internal fixation. It has been found that extracapsular hip fractures treated with internal fixation have more difficulty in full weight bearing of the affected leg compared to patients with intracapsular fractures operated with arthroplasty five days after operation (39). For the long-term outcomes, several studies has found that patients suffering from a hip fracture have decreased mobility and are less likely to mobilize in the community for up to 2 years after the fracture (40), and more patients will be dependent on a walking aid to mobilize (41). In general, patients living in a nursing home before the fracture occurs, have less recovery compared to home-dwelling patients (40). Maintaining good mobility is also essential for undertaking pADL and iADL.

ADL function is also affected by a hip fracture, with a large number of patients not regaining their pre-fracture function and subsequently losing independency in ADL (42). The consequences of a hip fracture on ADL will be discussed further in section 1.3.3.

Increased dependency due to reductions in mobility and ADL levels might increase the patients need for home-based services such as medical assistance, assistance in self-care or house cleaning, or change in accommodations. A hip fracture increases the risk of institutionalization, and for those still living at home increases the risk of needing assistance in ADLs (40, 41). Approximately 10-20% of hip fracture patients are newly institutionalized in industrialized countries (40), while for the patients still living at home after the hip fracture the probability of receiving help is increased by 55% (41).

Lastly, in addition to the physical trauma and subsequent consequences in physical functions, a hip fracture can also cause psychological trauma. Increased fear of falling is commonly reported after a hip fracture, with it being both a risk factor for new falls, but also an independent consequence of a fall (43). A study found that 49% of hip fracture patients had fear of falling up to six months after the hip fracture, and that it was associated with female gender, polypharmacy, poor daily functioning, poor physical performance and depression, but did not affect mortality, living arrangements or changes in mobility one year after hip fracture (43). Patients with severe fear of falling may reduce their participation in social activities and ambulate less frequently, which might exacerbate functional decline after a hip fracture (43).

Depression is also common after a hip fracture, and is associated with poorer outcomes (44). The prevalence of depression after a hip fracture is 23% (45), and severity of depression can predict health outcomes and functional recovery after a hip fracture, with hip fracture patients experiencing moderate to severe depression more likely to be less independent in walking, as well as institutionalized and have higher mortality rates one year after surgery (46). A suggested clinical cause of depression after hip fracture is the relationship between emotional state and performance improvement (45).

1.2 Orthogeriatrics

1.2.1 Background of orthogeriatrics

Orthogeriatrics is the co-operation between orthopedic surgeons and geriatricians in the management of hip fracture patients. These patients often have both frailty and fragility of the bone simultaneously (47). Therefore it is now largely recognized that hip fracture patients are geriatric patients with an orthopedic problem, making the treatment of the hip fracture a complex task, needing a holistic approach. A multidisciplinary orthogeriatric approach for treating these patients is now increasingly common, bringing skills from two specialties to deal with both the frailty and the fragility of the bone simultaneously (47).

Orthogeriatrics was developed in England in the 1950s (48, 49). Since then a variety of different orthogeriatric models have been implemented and tested worldwide; ranging from more simple models to more sophisticated models. Although, different orthogeriatric models have shown a positive effect on length of hospital stay (LOS), in-hospital mortality and 1-year mortality, as well as some complications (such as delirium), the effect on functional outcomes are inconsistent (50). Due to the heterogeneity in study design, patient selection and outcome measures there has been difficulty in concluding which orthogeriatric model is superior. And a recent systematic review suggest that there is still insufficient evidence to recommend which model is superior (50).

In the following sections the different orthogeriatric models will be introduced, as well as studies categorized to belonging to these models and evidence for their efficacy.

1.2.2 Different orthogeriatric models

There are different models of orthogeriatric care, according to how the collaboration between geriatricians and orthopedic surgeons is organized. In the literature it is common to categorize the different orthogeriatric models into three to five groups, depending on their organization (51-53), with some overlap. In this thesis, the four-category grouping of the different orthogeriatric models, suggested by Kammerlander (51), is used as a basis to differentiate between studies. The four categories are as follows:

I. Orthopedic ward and geriatric consultant service. In this model, the patient is treated in an orthopedic ward until discharge. A geriatric consultant service (a liaison service) will make an assessment of the patient upon request. This is the simplest model.

II. Orthopedic ward and daily consultative service. In this model the patient is treated in an orthopedic ward until discharge, but the geriatric consultant service is on a regular and daily basis until discharge.

III. Geriatric and rehabilitation ward and orthopedic consultant service. The hip fracture patient will be admitted to the geriatric ward in this model, and the treatment will occur here from admission to discharge, where the geriatricians will have the main responsibility for treatment. In this setting, the orthopedic surgeons act as a consultant service.

IV. Orthopedic ward and integrated care. This is the most advanced model, in which the geriatricians and the orthopedic surgeons collaborate on a daily basis on the treatment of hip fracture patients. The patients are admitted to an orthopedic ward, and the geriatrician is an integrated part of the multidisciplinary team treating the patients.

For the purpose of this thesis, the different studies are categorized according to these four categories, and additionally further grouped by time period (1980-1999, 2000-2010 and 2011-present) to illustrate the progression of orthogeriatric care over time, throughout the world.

1.2.3 The progression of orthogeriatrics

In recent years, many studies have been conducted to evaluate the effect of orthogeriatric care on hip fractures. In the following section the different studies will be presented briefly, according to time period.

1.2.3.1 Orthogeriatric studies in the period of 1980-1999:

Table 1 shows the studies conducted on orthogeriatric care in the time period of 1980-1999. Only eight studies on orthogeriatric care were conducted in this time period, of which only two evaluated the effect of a more sophisticated model (model III (54) and model IV (55)). Two of the studies conducted in this time period were prospective randomized (56, 57), while the rest used historical controls, and only two studies (55, 57) offered some sort of follow-up. All studies were either from Europe, UK, USA or Australia, none were from Asia, the Middle-East or South-America.

Table 1. Orthogeriatric studies in the period of 1980-1999

Study	Number of patients included	Study design	Follow-up	Outcome measures	Results and conclusion	Model
Boyd (54), 1983. UK.	N=771	Retrospective before and after	No follow up	LOS, mortality, waiting time for surgery and discharge destination	In the intervention group the LOS (66 vs. 48 days), waiting time for surgery (3 vs. 2.6 days) and in-hospital mortality (22% vs. 17 %) were reduced. Discharge destination did not differ.	**III**
Gilchrist (58), 1988. UK.	N=222	Prospective randomized	No follow up. Mortality registered at 3 and 6 months.	LOS, mortality, medical conditions and place of residence after discharge	There was no difference in LOS (10.2 vs. 9.8 days) or mortality during hospital stay, and after three and six months. Place of residence after discharge did not differ between groups. More new medical disorders were found in the intervention group.	**I**
Kennie (56), 1988. UK.	N=108	Prospective randomized	No follow up	LOS, physical independence at discharge and place of residence after discharge	More patients were physically independent in ADL at discharge in the intervention group, as well as having shorter LOS (24 vs 41 days). More patients were discharged to their own home (63% vs. 38%) in the intervention group	**I**
Gustafson (59), 1991. Sweden.	N=214	Prospective with retrospective controls	No follow up	Incidence delirium, delirium severity, delirium duration, LOS	The incidence of delirium was lower in the intervention study (47.6% vs. 61.3%, p<0.05). The delirium that occurred in the intervention study was also less severe, and had shorter duration. LOS was shorter in the intervention	**I**

				and complications	study (11.6 vs 17.4, p<0.001), and fewer patients developed postoperative complications. There was no difference between groups in mortality, discharge to long term care and use of walking aid after 6 months.	
Zuckerman (60), 1992. USA.	N=491	Prospective with retrospective controls	No follow up	LOS, post-operative complication, mortality and mobility	Significantly fewer patients had postoperative complications (38 vs 65 %, p<0.001), and significantly more patients were able to ambulate independently at discharge and at a greater distance (56 vs 18 %, p<0.001) after the introduction of the program. There were also fewer ICU transfers (p<0.05), and fewer discharges to nursing homes.	**II**
Antonelli Incalzi (61), 1993. Italy.	N=761	Prospective with retrospective controls	No follow-up	LOS, mortality and operation rate	After the implementation of the new model LOS (29 vs. 38 days, p<0.003) and mortality rate (18% vs. 8.4%, p<0.001) was significantly reduced, and the operation rate was higher (89.9% vs. 83.8%, p <0.02).	**II**
Swanson (57), 1998. Australia.	N=71	Prospective randomized	1 and 6 months. Data collected either at the 6 months out patient control or by telephone interviews	LOS, mortality and ADL	LOS was shorter in the intervention group (33 vs. 21 days, p<0.01). There were no differences between groups in mortality, ADL function, mobility or postoperative complications.	**II**
Lundström (55), 1999. Sweden.	N=49	Prospective with retrospective controls	6 months. Interviews with patients and caregivers	Delirium, LOS and mobility	There was no difference between groups in preoperative delirium, but the intervention resulted in lower incidence of postoperative delirium and shorter duration of delirium. More patients were discharged to independent living (33.3% vs. 92.6%, p=0.018) and were able to walk independently with walking aids at discharge (60% vs. 88.6%, p=0.003) in the intervention group. There was no difference between groups in LOS (12.5 days in both groups), in-hospital or six month mortality, or in patients living independently six months postoperatively.	**IV**

1.2.3.2 Orthogeriatric studies in the period of 2000-2010:

Table 2 shows an overview of the orthogeriatric studies conducted in the time period of 2000-2010. Twenty studies on orthogeriatric care were conducted in this time period, of which only four evaluated the effect of model I (62-65), meaning more studies evaluated the effect of an orthogeriatric model in which the geriatric input was at least daily. Eight of the studies had a prospective randomized study design (63, 64, 66-71), and the rest used historical controls. Eight of the studies included follow-up (62-65, 68, 69, 72, 73), either by interview of patient or next of kin or face-to-face evaluations of the patient. No study was from South-America, and most of the studies were from Europe or the UK.

Table 2. Orthogeriatric studies in the period of 2000-2010

Study	Number of patients included	Study design	Follow-up	Outcome measures	Results and conclusion	Model
Milisen (62), 2001. Belgium.	N=120	Prospective with retrospective controls	Telephone interview with relatives at one and three months postoperatively	Incidence delirium, severity and duration of delirium, cognitive functioning, functional rehabilitation, mortality and LOS	Reduction in duration and severity of delirium, but not incidence of delirium. Patients who developed delirium was more dependent in ADL both before and after the fracture. There was a trend towards lower LOS. The cognitive recovery was better in the intervention group.	**I**
Marcantonio (66), 2001. USA.	N=126	Prospective randomized	No follow up	Delirium and LOS	There were fewer patients with delirium in the intervention group (50% vs. 32%, p=0.04), and delirium was less severe. There was no difference between groups in regards to LOS or delirium duration. Patients without prefracture dementia or ADL function impairment benefitted the most from the intervention.	**II**
Khan (74), 2002. UK.	N=745	Prospective with retrospective controls. No randomization.	No follow up	LOS, mortality and discharge destination	There was no effect of the intervention on LOS (26 days in both groups), mortality or discharge destination.	**II**
Naglie (63), 2002. Canada.	N=279	Prospective randomized	3 and 6 months. Interviews with patients and caretakers	Mobility, mortality and place of residence	There was no difference between groups in regards to mobility three and six months postoperatively. LOS was longer in the intervention group (29 v 21 days, p < 0.001), but the mean number of days spent in an institution over the first six	**I**

					months postoperatively after surgery was similar.	
Adunsky (67, 75, 76), 2003, 2005, 2011. **Ginsberg (77), 2013. Israel.**	N=330	Prospective quasi-randomized controlled	No follow up	LOS, mortality and function at discharge	LOS was shorter (32 vs. 27 days, p<0.01) in the intervention group. Patients treated in the intervention group also had an almost two-fold chance of successful rehabilitation defined as more than 50 % increase in "relative functional gain". Lower mortality rates at 1, 3 months and 1 year. The model is cost-effective	**III**
Koval (72), 2004. USA.	N=1065	Prospective with retrospective controls	3,6,12 months and then every 6 months until death. Interviews with patients or family member	LOS, mortality and mobility	LOS (22 vs. 14 days, p<0.001), in-hospital mortality (5% vs. 2%, p<0.001) and 1-year mortality (14% vs. 9 %, p<0.01) was significantly reduced in the intervention group There were no effect of the intervention on ambulation, discharge destination or revision of surgery.	**II**
Roberts (78), 2004. UK.	N=395	Prospective before and after	No follow up	LOS, mortality, complications, readmissions and mobility.	After the implementation of the intervention LOS increased (23 vs. 16 days, p<0.0005) and more patients could walk independently at discharge (73% vs. 63%, p=0.033). There was a significant reduction in pressure ulcers, urinary tract infections and wound infections in the intervention group, but the number of cardiac complications registered in the intervention group was higher. There was a trend towards reduction in admission to long term care.	**II**
Khasraghi (79), 2005. USA.	N=510	Retrospective before and after chart review	No follow up	LOS, waiting time for surgery, complications and discharge destination	Postoperative complications were lower in the intervention group (51% vs. 36%). Patients in the intervention group spend a mean 1.9 hours less in the emergency department, and both the waiting time for surgery (46 vs. 26 hours) and LOS (8.1 vs. 5.7 days) were reduced. Significantly fewer were discharged to nursing homes (23% vs. 13%) in the intervention group. There was a trend towards lower in-hospital mortality in the intervention group.	**IV**
Shuy (64, 80-82), 2005, 2008, 2010,	N=162	Prospective randomized	1,3,12 and 24 months. Face-to-face	Physical function, mobility, pain,	More patients recovered their previous walking ability and ADL	**I**

2012. **Liu (83), 2014. Taiwan.**		(using flip of a coin).	evaluation with a combination of performance based and self-reported measures. Assessors not blinded	depression, nutrition, function and balance	function in the intervention group, and the effect lasted for 24 months. In addition there were fewer depressive symptoms, better ratio of hip flexion and fewer falls after 2 years in the intervention group. More patients recovered their previous walking ability and ADL function among the cognitively impaired. A nutritional component (an in-home program) in the comprehensive care model effectively improved nutritional status, which in turn was associated with better functional recovery and balance.	
Vidán (68), 2005. Spain.	N=321	Prospective randomized controlled trial	3,6,12 months. Interviews with patients and relatives	LOS, complications, mortality and ADL recovery	The LOS was shorter in the intervention group (16 vs. 18 days, p=0.06). The in-hospital mortality (0.6% vs. 5.5%, p=0.03), and medical complications (45% vs. 61%, p=0.003) were lower in the intervention group. There was no difference between groups in regards to ADL and ambulation at six and 12 months postoperatively, but there was a trend towards better ADL recovery in the intervention group at 3 months follow-up (53% vs 43%, p=0.10).	**II**
Wong Tin Niam (84), 2005. Australia.	N=99	Prospective before -after	No follow up	Delirium and LOS	Incident delirium was reduced (12.7% vs 37.5%, p=0.012), after implementation of the intervention. There was no difference in LOS (12.1 vs 11.8 days).	**II**
Barone (73), 2006. Italy.	N=819	Retrospective before and after	12 months. Telephone interview were conducted	LOS and mortality	The one year survival of those treated in the orthogeriatric unit was higher compared to those admitted before and after the unit was closed (75% vs. 65% vs. 67%, respectively). In-hospital mortality was significantly lower compared to the group admitted before the intervention (p=0.03) and similar to the group admitted after the intervention unit was closed (p=0.34). There was no difference in LOS between groups.	**II**
Fisher (85), 2006. Australia.	N=951	Prospective with	No follow up.	LOS, mortality and complications	In hospital mortality (4.7% vs. 7.7%, p<0.01), postoperative complications (49.5% vs. 71.0%,	**II**

		retrospective controls			p<0.001) and readmissions the first six months postoperatively (28% vs. 7.6%, p<0.001) was reduced in the intervention group. LOS was 11 days in both groups, and there was no difference in discharge destination.	
Stenvall (69, 86, 87), 2007, 2012. **Lundstrom (88), 2007. Sweden.**	N=199	Prospective randomized controlled	Home visits 4 and 12 months performed by research nurses	LOS, mortality, postoperative complications, delirium and ADL	Patients treated in the intervention group were more likely to regain independence in pADL at 4 (OR 2.5) and 12 months (OR 3.5) postoperatively. More patients in the intervention group were able to walk alone indoors without walking aids (OR 3.01) at 1-year follow up. There was no difference between groups in re-admissions or mortality rates. Fewer patients in the intervention experienced delirium postoperatively (75% vs. 55 %, p=0.003) and the duration was also shorter (10 vs. 5 days, p=0.009). For patients with cognitive impairment the intervention was effective in reducing postoperative delirium (97% vs. 68%, p=0.002), urinary tract infections (64% vs. 21%, p=0.001) and falls (34 vs. 1, p=0.006) during the hospital stay.	**III**
Friedman (89, 90), 2008, 2009. **Kates (91-93), 2010, 2011. USA.**	N=314	Retrospective chart review. Data compared to other hospitals, historical data and national average	No follow up	LOS, waiting time for surgery, mortality and re-admissions	The waiting time for surgery (24 vs. 37 hours, p=0.007) and LOS (4.6 vs. 8.3 days, p<0.001) was shorter in the intervention group. Patients in the intervention group also had fewer complications (31% vs. 46%, p=0.005). There was no difference in regards to in-hospital mortality rate or the 30-day readmission rate between groups. This model was found to be cost-effective by reducing LOS and in-hospital complications.	**IV**
Ho (65), 2009. **Leung (94), 2011. China.**	N=565	Retrospective before and after chart review	3 and 12 months. Data collected from regular out-patients visits	LOS, waiting time for surgery and mortality	The intervention had shorter LOS (9.7 v 8.3 days, p=0.001), lower in hospital (4 v 1 %, p=0.02) and 1-year mortality (20 v 11 %, p=0.005). There was shorter waiting time to surgery (mean 55 v 45 hours, p=0.02) and lower cost of the intervention. More patients were independent in ADL after 3 and 12 months, and more patients could walk unaided.	**I**

Miura (95), 2009. USA.	N=161	Prospective with retrospective controls	No follow up	LOS, mortality and cost	The LOS was reduced (6.1 vs. 4.6, p<0.001) and more were operated before 24 hours (50.5 vs 22.2 %, p<0.001) in the intervention group. The intervention showed a reduction in cost, and was deemed cost effective.	**III**
Cogan (96), 2010. Ireland.	N=201	Retrospective chart review before and after	No follow up	LOS, mortality and waiting time for surgery	There was no effect of the intervention on T waiting time to surgery (1.9 days in both groups). LOS was longer in the intervention group (23 vs. 30 days), but the in hospital mortality (20% vs. 8 %) and 1-year mortality (45% vs. 34 %) was reduced. Institutionalization was increased (23% to 29%), and more patients were independent at home (32% vs. 38%) at one year follow-up. The routines for prescription of bisphosphonates became better after intervention.	**II**
Mazzola (70), 2010. Italy.	N=261	Prospective quasi-randomized controlled (by availability of beds)	No follow up	LOS, waiting time for surgery and mobilization time	Patients treated in the intervention group had shorter mobilization time (2.9 vs 3.6 days, p=0.01). LOS was 13 days in both groups. There were no differences between groups in regards to waiting time for surgery (mean 2.8 days in both groups) or mortality.	**III**
González-Montalvo (71), 2010. Spain.	N=224	Prospective quasi-randomization (alternate days and bed-availability)	No follow up	LOS, waiting time for surgery, mobility at discharge and discharge destination	Patients treated in the intervention had shorter time to geriatric assessment (1 vs. 4 days, p<0.001) waiting time for surgery (5 vs. 6 days, p<0.001) and LOS (12 vs. 18 days, p<0.001). There was no difference between groups in regards to in-hospital mortality, mobility at discharge or place of discharge.	**IV**

1.2.3.3 Orthogeriatric studies in the period of 2011-present:

An overview of the studies conducted on orthogeriatric care from 2011 to present day is presented in Table 3. Fifty-one studies on orthogeriatric care were conducted in this time period. Only seven studies evaluated the effect of model I (97-103), and approximately half of the studies (twenty-eight) evaluated the effect of model IV (104-131), with an integrated care ward, and only four studies evaluated the effect of model III (5, 29, 132, 133), with a geriatric ward. Again, there is a shift towards more studies implementing geriatric input on a regular basis. Most of the studies were retrospective or had historical controls. Eleven of the studies offered follow-up either by telephone interview or face-to-face evaluations (5, 29, 97, 102, 108, 112, 113, 130, 133-135). Most studies were from Europe, only one from South-America (136), seven from Asia (99, 128-131, 137, 138) and two from the Middle-East (132, 139).

Table 3. Orthogeriatric studies in the period of 2011-present

Study	Number of patients included	Study design	Follow-up	Outcome measures	Results and conclusion	Model
Deschodt (97, 140, 141), 2011, 2012. Belgium.	N=177	Prospective controlled study.	6 weeks, 4 and 12 months. Telephone interview with patients or relatives	Functional status, LOS, mortality, new nursing home admissions and delirium	Incident postoperative delirium was reduced in the intervention group (53 v 37 %, p=0.04), but there was no reduction in severity or duration. There were no other differences in outcome measures.	**I**
Gregersen (142), 2012. Denmark.	N=495	Retrospective chart review before and after	No follow up	LOS, mortality and re-admissions	Median LOS was reduced from 15 to 13 days in the intervention group. There was no effect of the intervention on re-admissions, mortality or discharge destination. More patients began treatment for osteoporosis, and there was a non-significant decrease in the risk of new fractures after two years.	**II**
Dy (104), 2012. USA.	N=306	Retrospective chart review before after	No follow up	LOS, waiting time for surgery, mortality and complications	Patients in the intervention group had fewer occurring complications (50% vs. 34.6%, p=0.002), but there was no difference between groups in regards to waiting time for surgery (1.4 vs. 1.5 days, p=0.62), LOS (7 vs. 8.4 days, p=0.50) or readmission rates. Additionally, there was a non-significant higher 1-year mortality in the intervention group (20.3% vs. 12.5%, p=0.16).	**IV**

Wagner (136), 2012. Chile.	N=275	Prospective with retrospective controls	No follow up	LOS, mortality and complications	There was no difference between groups in LOS (9 vs. 8 days, p=0.51), in-hospital mortality (2.2% vs 1.1%, p=0.46) or 1 year survival (87% in both groups), as well as hematocrit at discharge, transfers to internal medicine or the intensive care unit and readmissions. Registration of postoperative complications were increased in the intervention group.	**II**
Bhattacharyya (143), 2013. UK.	N=523	Retrospective chart review before and after	No follow up	LOS, mortality and discharge destination	The proportion of patients that returned to their pre-fracture residence was increased (73% vs. 57%, p<0.001) and the staff was more satisfied with the new model. There was a non-significant reduction in LOS (19.5 vs. 25 days, p=0.22) and in-hospital mortality (8.4% vs. 12.4%, p=0.26).	**II**
Flikweert (134, 144), 2013, 2014. Netherlands.	N=401	Prospective with retrospective controls	Follow up at 6 weeks, 3 and 6 months after surgery	Preoperative fasting time, waiting to surgery, LOS, discharge destination, complications, delirium and mortality	Median preoperative fasting time was significantly lower in the intervention group (9 vs. 17 hours, p<0.001). The number of patients that had to wait more than one day for surgery was also lower (8% vs. 15%, p<0.005). LOS was significantly shorter (7 vs. 11 days, p<0.001). In-hospital mortality was lower (2% vs. 6%, p<0.05), there was no difference in 30-day mortality. No other outcome measure was significantly different between groups.	**II**
Burgers (98), 2014. Netherlands.	N=526	Retrospective before and after. Chart review.	No follow up	LOS, mortality, complications and readmissions	LOS was significantly reduced (9 vs. 6 days, p<0.001). No difference in mortality, complications or readmissions.	**I**
Gupta (105), 2014. United Kingdom.	N=494	Prospective, cohort observational study with retrospective controls	No follow up	Time to surgery and LOS	Significantly more patients were operated within 48 hours in the intervention group (86% vs 77% p=0.013), and the LOS was significantly shorter (19.3 vs. 15.1 days, p=0.013)	**IV**
Suhm (106), 2014. Switzerland.	N=493	Prospective, cohort observational study with a retrospective (historical) control.	No follow up.	LOS, 1-year mortality, change in residential status.	LOS was significantly shorter in the intervention (8.6 vs. 11.3 days, p < 0.01) and patients were less likely to experience a complication (59% vs. 73%, p < 0.01) while being in the hospital. There was no significant difference in 1-year mortality or in change of residential status	**IV**
Watne (5), 2014. Norway.	N=329	Prospective randomized controlled trial	Follow-up at 4 and 12 months at an	Cognition (combined CDR and 10 word memory task),	There was no difference in delirium rates, delirium duration or delirium severity. There was a non-significant longer waiting time to	**III**

			outpatient clinic	delirium, LOS, cognition, mobility, place of residence, ADL and mortality	surgery in the intervention group. The intervention group performed better in CERAD immediate and delayed, clock drawing test, MMSE, CDR and ADL (both BADL and NEADL), but none of these differences were significant. No significant difference in new nursing home admissions. Fewer patients in the intervention group were discharged with ongoing delirium (15% vs. 26%, p=0.01). The LOS was longer in the intervention group (median 11 vs. 8 days, p<0.001). Better mobility four months after surgery, measured with SPPB (median 4 vs. 3, p=0.13). There was no difference in four months mortality (17% vs. 15%, p=0.05.)	
Prestmo (29, 145), 2015, 2016. **Taraldsen (146), 2015.** **Thingstad (147), 2016.** **Heltne (148), 2017.** **Norway.**	N=397	Prospective randomized controlled trial.	The patients were assessed in the outpatient clinic 1,4,12 months by research assistants blinded to allocation	Mobility, LOS, mortality, health economics, place of residence and ADL	LOS was significantly longer (between group-difference 1.7, p=0.025), and more patients were discharged directly home (between group-difference 13.9, p=0.001) in the intervention group. Mobility measured by SPPB were better in the intervention group at four months (between group-difference 5.12 vs. 4.38, p=0.01) and 12 months (between group-difference 0.69, p=0.023). ADL was significantly better in the intervention group; both BADL and NEADL at both 4 and 12 months. Fear of falling was reduced and quality of life was also better in the intervention group. There was no difference between groups in waiting time for surgery, number of new nursing home admissions or mortality. The intervention care index stay was more costly than standard care, with a mean difference of 2331 euro, p<0.0001, but more cost-effective long-term. Participants who received intervention had significantly higher gait speed, less asymmetry, better gait control and more efficient gait patterns.	**III**

					More polypharmacy was found in the intervention group (84.3% vs. 70.5%, p=0.0015), as well as.more withdrawals (209 vs. 82, p<0.0001), and a higher number of start (844 vs. 526, p<0.0001).	
Soong (149), 2016. Canada.	N=571	Single center pre-post study	No follow-up	LOS, cost per case, time to surgery, osteoporosis treatment, preoperative echocardiogram utilization, mortality and readmission	LOS decreased from 18.2 to 11.9 days (p<0.001). Mean cost per case decreased by $4953 (p<0.001). Mean time to surgery (45.8 vs. 29.7 hours, p<0.001) and use of preoperative echocardiogram (15.8% vs. 9.1%, p<0.05) decreased. Initiation of osteoporosis treatment increased (96.4% vs. 55.8%, p<0.001). There was no significant difference between groups in regards to mortality rate and readmission rate.	**II**
Rostagno (133), 2016. Italy.	N=458	Prospective with historical controls	Follow up at 3 months by telephone interview	LOS, mortality, postoperative complications and functional recovery	LOS was significantly lower (13.6 vs. 17 days, p=0.0001) in the intervention period, and the intervention group had a low number of postoperative complications (8%). Patients that underwent surgery before 48 hours were also significantly higher in the intervention period (54% vs. 26%, p=0.0001). Full functional recovery was seen in almost half of the patients in the intervention group.	**III**
Stenqvist (111), 2016. Denmark.	N=1982	Retrospective cohort with historical control group	No follow up	Mortality	In-hospital mortality was 6.3% in the control group and 3.1% in the intervention group (p=0.0009). Mortality at 1 and 3 months, and 1 year did not differ between groups. Mortality was significantly reduced at all time points when adjusted. **Sub group analyses on mortality:** Mortality for **home-dwelling patients**: 8.3% vs 2.0%, (p<0.0001) in-hospital, 12.2% vs. 6.8% (p=0.004) at 30 days, and 20.5% vs. 13% (p=0.002) at 90 days. 1 year mortality not significant. Mortality for **nursing home patients**: non-significant difference for all time points.	**IV**
Middleton (110), 2016. England.	N=1894	Retrospective before and after (Kammerlander 1 compared to Kammerlander 4 – post-intervention)	No follow up	Mortality, LOS and time to surgery	Despite frailer population in the post-intervention group: Time to surgery was shorter (41.8 vs. 27.2 hours, p<0.001) and LOS was shorter (27.5 vs. 21 days, p<0.001). Mortality dropped significantly from 13.2% to 10.3%, p=0.04.	**IV**

					Time taken before orthogeriatric review was also improved in the post-intervention group: 53h to 23h, p=0.001.	
Gosch (108), 2016. Germany.	N=265	Prospective cohort study (comparing with literature)	3, 6 and 12 months through interviews	Function, mobility, mortality	Nearly half of the cohort regained their pre-fracture mobility at 12 months 29.4% died during the first year and 70.6% died during the entire observation time. 23.4% sustained a second fracture, and 3.4% sustained more than one fracture. 10.9% had recurrent fractures during the first year.	**IV**
Forni (107), 2016. Italy.	N=23,973	Retrospective observational study (comparing Kammerlander 4 (MCM) to Kammerlander 1 (UCM))	No follow up	30-day mortality	The multilevel analysis showed that mortality was significantly higher in the UCM, after adjusting for gender, age, comorbidity and timing of surgery (OR=1.32; 95% IVCI 1.09-1.59; p=0.004). Surgical delay was not significantly associated with higher mortality rates.	**IV**
Kristensen (109), 2016. Denmark.	N=11,461	Population-based cohort study (prospective collection of data from registry). Comparing Kammerlander 4 to Kammerlander 1.	No follow up	Quality of care (using six process performance measures), 30-day mortality, time to surgery and LOS	Admittance to orthogeriatric units was associated with a higher chance for fulfilling five out of six process performance measures. Patients who were admitted to an orthogeriatric unit experienced a lower 30-day mortality (adjusted odds ratio (aOR) 0.69; 95% CI 0.54-0.88), whereas the LOS (adjusted relative time (aRT) of 1.18; 95% CI 0.92-1.52) and the time to surgery (aRT 1.06; 95% CI 0.89-1.26) were similar.	**IV**
Anderson (150), 2017. USA.	N=271	Retrospective cohort study	No follow-up	LOS, time to surgery, discharge status and readmission rate	LOS decreased after the implementation of the intervention (6.4 vs. 5.5 days, p=0.004), as well as a trend towards lower time to surgery (29.0 vs 26.5 hours, p=0.168). The readmission rate remained stable (3.2% vs. 2.7%, p=0.520), and there was no change in discharge destination (21% vs. 16% discharged home, p=0.244).	**II**
Folbert (112), 2017. Netherlands.	N = 1385	Prospective cohort with historical controls	1 year follow up, collected data from outpatient clinic visits	In-hospital and 1-year mortality and associated risk factors	The analysis demonstrated that the 1-year mortality rate was 23.2 % (n = 197) in the intervention group compared to 35.1 % (n = 188) in the historical control group (p < 0.001). Independent risk factors for 1-year mortality were male gender (odds ratio (OR) 1.68), increasing age (OR 1.06), higher American Society of Anesthesiologists (ASA) score (ASA 3 OR 2.43, ASA 4-5	**IV**

					OR 7.05), higher Charlson Comorbidity Index (CCI) (CCI 1-2 OR 1.46, CCI 3-4 OR 1.59, CCI 5 OR 2.71), malnutrition (OR 2.01), physical limitations in activities of daily living (OR 2.35), and decreasing Barthel Index (BI) (OR 0.96).	
Henderson (113), 2017. Ireland.	N=454	Prospective cohort with historical controls	Offered follow up at a dedicated fracture liaison secondary prevention clinic	LOS, mortality, use of medical and rehabilitative services and level of dependency at discharge	Patients in the orthogeriatric service group experienced significant reductions in 1-year mortality (chi2 = 13.34, P < 0.001), length of acute hospital stay (U = -3.77, P < 0.001) and requirements for further rehabilitation (chi 2 = 26.59, P < 0.001). Patients in the pre-service establishment group were significantly more dependent following their fracture than the patients in the orthogeriatric service group (chi 2 = 5.34, P = 0.021).	**IV**
Chen (99), 2019. Taiwan.	N=313	Retrospective cohort	No follow-up	1-year mortality	1-year mortality was lower in the orthogeriatric group (4.7% vs 14.0%). Patients not receiving orthogeriatric care were 2.89 times (95% confidence interval [CI] 1.07-7.81) more likely to die 1-year after discharge. Mortality was associated with postoperative complications and elevated comorbidity.	**I**
Wallace (151), 2019. USA.	N=243	Retrospective cohort study	No-follow-up	1-year mortality	The post-intervention cohort had significantly higher overall survival (HR for death=0.43, 95% CI 0.25-0.74, p=0.002).	**II**
Jackson (114), 2019. USA.	N=2895	Pre- and post-comparison after implementing an interdisciplinary care pathway	No follow-up	LOS, time to surgery and discharge status	Mean LOS decreased after implementation of the intervention (from 5.6 to 4.7 days, p=0.046). Time to surgery decreased from 30.8 to 25.6 hours. The percentage of patients discharged home from the hospital remained stable before and after the implementation of the intervention.	**IV**
O'Mara-Gardner (100), 2020. USA.	N=639	Prospective cohort with retrospective controls	No follow-up	LOS, time to surgery, 30-day readmission rate and 30-day mortality	LOS decreased significantly with implementation (7.2 vs. 5.4 days, p<0.001). Mean time to surgery decreased (22.79 vs. 30.23 hours, p<0.001) in the intervention group. The proportion of patients treated surgically within 24 hours also increased. (There was a trend towards lower readmission rates (13.5% vs. 11.1%, p=0.37) and a higher 30-day mortality rates (8.4% vs. 12.1%, p=0.14) in the intervention group.	**I**

Van der Zwaard (101), 2020. Netherlands.	N=430	Retrospective cohort	No follow-up	Number of hip fracture patients who opted for non-surgical treatment, reasons for non-surgical treatment, duration of life and location of death	Significantly more hip fracture patients (or representatives) elected non-surgical management of the hip fracture (9.1% vs. 2.7%, p=0.008). Reasons for not undergoing surgery were aversion to be more dependent on others and severe dementia. Median survival was median 5 days, and most patients died in a nursing home.	**I**
Werner (102), 2020. Germany.	N=207	Retrospective cohort	3-months follow-up by questionnaire and phone interview	Mobility, quality of life, operation duration, LOS, time to surgery, time in the intensive care unit, amount of blood transfused, place of discharge, mobilization during hospital stay, mobility at discharge, complications and mortality during hospital stay	LOS (7.8 vs. 9.1 days, p=0.022) and waiting time to surgery (25.4 vs. 35.8 hours, p=0.013) was shorter in the intervention group. There were no difference between groups in regards to complication or mortality rates during hospital stay or at 3-months follow-up. There were no other differences between groups.	**I**
Aletto (115), 2020. Italy.	N=352	Retrospective cohort study	No follow-up	LOS	A statistically significant reduction in LOS after implementation of the integrated care model (12.2 vs. 10.8 days, p<0.001).	**IV**
Lieten (116), 2020. Belgium.	N=251	Retrospective before and after comparing Kammerlander 1 to Kammerlander 4 (OG-CM)	No follow-up	Number of diagnoses, discharge status, 1-year readmission rate, in-hospital and 3-months mortality	The number of diagnoses increased (p=0.011), and the number of readmissions within a year were significantly lower in the OG-CM group (0.31 vs. 0.89 readmissions per patient, p=<0.001). There were no significant difference between the groups in regards to mortality in-hospital or at 3-months.	**IV**
Pablos-Hernández (117), 2020. Spain.	N=2741	Retrospective before and after, comparing usual care to Kammerlander 1, to Kammerlander 4	No-follow-up	LOS, time to surgery, post-surgical stay and in-hospital mortality	After implementation of the Orthogeriatric Unit Model there was a decrease in LOS (median 9 vs. 11. Vs 10 days, p<0.001) and time to surgery (median 3 vs. 4 vs. 3 days, p<0.001). There was also a reduction in in-hospital mortality, but with no statistical significance. In addition, more patients received surgical treatment before 24 h after the implementation (24.8% vs. 6.7% vs. 5.1%, p<0.001).	**IV**

Rapp (118), 2020. Germany.	N=58 001	Retrospective observation study, comparing hospitals with and without orthogeriatric co-management	No follow-up	Cumulative mortality	Crude 30-day mortality was lower in patients from hospitals with orthogeriatric co-management (10.3% vs. 13.4%). The adjusted 30-day mortality was 22% lower for patients in hospitals with orthogeriatric co-management. Mean length of stay was longer in hospitals with orthogeriatric co-management (mean 19.8 vs 14.4 days).	**IV**
Schuijt (119), 2020. Netherlands.	N=806	Retrospective cohort study	No follow-up	Postoperative complications, mortality, time spent at the emergency department, time to surgery and LOS	There was a significant decrease in postoperative complications (42% vs. 49%, p=0.034), and time at the emergency department was reduced by 38 minutes after the implementation of the intervention (160 vs. 198 minutes, p<0.001). There were no significant difference between the groups in time to surgery and LOS. Patients receiving care in the orthogeriatric trauma unit had a lower chance of complications (OR 0.654, 95% CI 0.471-0.908, p=0.011) and a lower chance of 1-year mortality (OR 0.656, 95% CI 0.450-0.957, p=0.029).	**IV**
Tittel (120), 2020. Germany.	N=605	Prospective cohort with historical controls	No follow-up	Evaluate the feasibility and effectiveness of the clinical pathway	There was s significant decrease in time to surgery, and a significant increase in patients included in the early rehabilitation program. A significantly greater number of patients could be discharged home or to rehabilitation. There was no difference in LOS detected. In addition, there was a significant decrease of hospital acquired pneumonia, as well as an increase in detected decubiti, urinary tract infections and postoperative delirium. There was no difference in mortality, revisions, failure of osteosynthesis, local complications (infections, hematoma) and internal complications (e.g. renal failure) before and after implementation.	**IV**
Lee (103), 2021. Canada.	N=212	Retrospective pre- and postintervention single-site study	No follow-up	LOS, incidence of postoperative delirium	There was no difference between groups in regards to incidence of postoperative delirium (26.3% vs. 26.5%, p=0.98) and LOS (IQR 4-10 vs. 5-10days, p=0.32). The rates of assessment of mental status, falls and bone health, identification of delirium prevention strategies, prescription of vitamin D or calcium or both and	**I**

					recommendation for antiresorptive therapy improved (p<0.001 for all).	
Flikweert (135), 2021. Netherlands.	N=357	Multicenter prospective controlled trial	3 weeks and 6 months after surgery	Functional outcome and living situation 6 months after surgery	There was no difference between groups in regards to rate of return to pre-fracture ADL level (56% vs. 63%). There were no significant differences between groups in regards to quality of life, return to pre-fracture living situation, ADL or mortality 6 months postoperatively. LOS was shorter in the intervention group (7 vs. 10 days, p<0.001).	**II**
Marcheix (152), 2021. France.	N= 534	Retrospective cohort study	No follow-up	LOS, institutionalization and mortality rates	LOS was reduced by one day (median 10 vs. 9 days, p=0,001). There was no difference between groups in waiting time to surgery, intra-hospital mortality rate, place of recovery, rate of institutionalization after 6 months or mortality rate at 6 months.	**II**
Bugaevsky (132), 2021. Israel.	N=441	Retrospective cohort, comparing Kammerlander 1 to Kammerlander 3	No follow-up	Compare demographics and clinical outcomes for older patients with a hip fracture	Patients admitted to the geriatric ward were older, more cognitively and functionally impaired, and had more comorbidities and polypharmacy. The LOS was also longer in this group (12.1 vs. 8.3 days, p<0.001), and they had more postoperative complications. There was no difference between the groups in regards to rehabilitation LOS and functional independence improvement. 1-year mortality rate was lower in the patients admitted to the orthopedic ward.	**III**
Pollmann (121), 2021. Norway.	N=297	Prospective observational study	No follow-up	Incidence delirium and subsyndromal delirium (SSD)	Fewer patients in the intervention group developed SSD or delirium (no delirium: 59% vs. 40%/SSD: 6% vs. 13%/delirium: 35% vs. 47%; p=0,021).	**IV**
Quaranta (122), 2021. Germany	N=620	Retrospective cohort study	No follow-up	Blood loss and number of transfusions	The Hb at discharge was significantly higher in the intervention group (10.27 vs. 10.07, p=0.003). For the hip fracture patients operated with hemiarthroplasty the Hb at discharge was higher (10.43 vs. 9.96, p=0.0001) and number of transfusions were lower (1.31 vs. 1.7, p=0.03) in the intervention group.	**IV**

Schulz (123), 2021. Germany.	N=24 517	Retrospective cohort study	No follow-up	Economic evaluation of the German orthogeriatric co-management (OCGM) model	Total average health costs per patient were higher in the OCGM group (p<0.001).	**IV**
Van Leendert (124), 2021. Netherlands.	N=300	Pseudo-randomized retrospective observational trial	No follow-up	Mortality at 3 months and 1 year, LOS and discharge status	Mortality rates were lower in the intervention group (3 months: 9.0% vs. 24.4%, p<0.001 and 1 year: 13.9% vs. 34.0%, p<0.001). LOS were shorter in the intervention group (7 vs. 9 days), but not statistically significant. More patients receiving intervention were discharged home (40.4% vs. 27.5%, p=0.023).	**IV**
Ogawa (137), 2022. Japan.	N=864	Retrospective cohort (using difference-in-difference approach (DD) to compare Kammerlander 1 to Kammerlander 2, then further comparison is made with another group from other hospitals with no change in care policy)	No follow-up	LOS, time to surgery, in-hospital mortality, perioperative complications, walking function at discharge and discharge to home	The intervention significantly reduced the change in mean length of stay (mean difference -12.9 days, p = 0.007) and discharge to home tended to change less frequently (-12.6%, p = 0.10). There was no significant reduction in mean time to surgery (-0.2 days, p = 0.83), mortality (-0.8%, p = 0.62), or complications (-1.0%, p = 0.85). There was no increase in independence of walking at discharge (-0.4, p=0.94).	**II**
Saber (139), 2022. Egypt.	N=128	Prospective cohort with retrospective controls	No follow-up	Time to surgery, LOS, degree of postoperative pain improvement and susceptibility to depression	Time to surgery (7 vs. 1 days, p<0.001) and LOS (13.8 vs. 7.0 days, p<0.001) was shorter in the intervention group. No significant difference was found between groups regarding the number of patients treated operatively, degree of postoperative pain improvement or susceptibility to depression.	**II**
Zhu (138), 2022. China.	N=155	Prospective cohort study	No follow up	Time to surgery, LOS, 48h operation rate, incidence of postoperative delirium, ADL score before discharge	There was a significant increase in 48h operation rate (32.9% vs. 11.8%, p<0.001), and decrease in preoperative waiting time (5.9 vs. 8.7 days, p<0.001), LOS (20.8 vs. 23.6 days, p<0.001) and incidence of postoperative delirium (21.4% vs. 31.8%, p<0.001). There was no difference in ADL scores between groups at discharge.	**II**
Balvis-Balvis (125), 2022. Spain.	N=633	Retrospective observational cohort study	No follow-up	LOS, time to surgery, mortality and perioperative complications	In-hospital mortality decreased in the intervention group (3.6% vs. 10%, p=0.004), but there was no difference between groups at 30 days or 1 year. LOS was shorter in the intervention group (12.8 vs.	**IV**

					17.6 days, p<0.001), as was time to surgery (4.9 days vs. 6 days, p=0.029). Perioperative complications measured as acute urinary retention and pressure ulcers also decreased in the intervention group (p<0.001).	
Casanova Querol (126), 2022. Spain.	N=911	Pre- and post-intervention prospective study	No follow-up	LOS, complications, time to surgery, hospital readmissions, mortality and function	LOS was shorter in the intervention group (16.9 vs. 15.6 days, p=0.014). There was improved osteoporosis treatment prescribing (51.6% vs. 88%, p<0.001) and episodes of delirium was reduced (44% vs. 31.2%, p<0.001). In addition episodes of bronchospasm, heart failure and COPD exacerbation was reduced in the intervention group. There was, an increase in pressure ulcers at discharge (2.9% vs. 9%, p<0.001). There was no difference in percentage of operations in less than 48h, function at discharge, hospital readmissions or mortality.	**IV**
Fluck (127), 2022. United Kingdom.	N=3972	Retrospective cohort	No follow-up	Temporal trends in the annual percentage change (APC) of postoperative outcomes and discharge destination	Patients operated after 36 hours decreased, and hip fracture surgery increased progressively in patients > 90 years old and those with an ASA score ≥ 3. There was also a decline in pressure ulcers amongst patients < 90 years old and a decline in mortality amongst those > 90 years old. Prolonged length of stay (> 23 days) and new discharge to nursing care declined. The rate of patients returning home was decreasing, whilst new discharge to rehabilitation was increasing.	**IV**
Heyzer (128), 2022. Singapore.	N=3057	Descriptive study, comparing each year of the intervention to each other over five year period (the first year was treated as baseline)	No follow-up	Evaluate how the intervention improved process and outcome measures	There was an increase in surgeries performed within 48 hours (32.5% to 80.1%), a reduction in non-operated patients from 19.6% to 11.9%, a reduction in LOS among surgically (from 14.0 to 9.9 days) and conservatively managed patients (from 19.1 to 11.0 days), a reduction in 30-day readmission rate from 3.2% to 1.6% and improved Modified Functional Assessment Classification of VI to VII at six months from 48.0% to 78.2%.	**IV**
Higashikawa (129), 2022. Japan.	N=292	Retrospective cohort study	No follow-up	Evaluate the effect of orthogeriatric co-management	The number of medicated drugs significantly decreased from 6.03 on admission to 5.50 at discharge in the intervention group. The recovery rate from postoperative urinary retention increased	**IV**

					significantly from 57.8% vs. 84.3% (p=0.049). There was no difference between groups in mortality.	
Liu (130), 2022. China.	N=886	Pre-post intervention retrospective cohort study	1 year follow-up (phone interview)	Time to surgery, perioperative complications, mortality and functional outcomes	Time to surgery was lower (141.0 vs. 67.3 hours, p<0.001) and LOS was shorter (10.6 vs, 7.6 days, p<0.001) in the intervention group. There was no difference between groups in perioperative complications. Mortality rate showed no difference for up to 1 year after surgery after regression analysis. There were no differences between groups in pre-injury mobility nor 1-year follow-up mobility assessed by the Parker score. Only half of the patients in both groups returned to their pre-injury mobility level.	**IV**
Yee (131), 2022. China.	N=484	Prospective cohort study	No follow-up	LOS (hospital and convalescent hospital), time to surgery, mortality, complications, delirium, osteoporosis management, functional improvement, discharge destination and readmission rates	Median LOS in the acute and rehabilitation hospitals decreased by 1 day and 2 days, respectively (P=.001). The intervention group was associated with a higher Modified Barthel Index score on discharge from the rehabilitation hospital and more patients in the intervention group received osteoporosis medication prescription within one year after the index fracture. There was no difference in the 28-days unplanned readmission rate, complication rate, mortality rate or Elderly Mobility Scale scores on discharge from the rehabilitation hospital between the two groups.	**IV**

1.2.3.4 The efficacy of orthogeriatric care

Compared to traditional orthopedic care, orthogeriatric management of hip fracture patients have been reported to be more beneficial. A meta-analysis conducted by Lin et al. in 2020, showed that comprehensive geriatric care (CGC) and comprehensive geriatric assessment (CGA) reduced the in-hospital mortality, the overall mortality rate and increased ADL levels compared to traditional orthopedic care in 11 RCTs (153). There was no difference in LOS or new nursing home admissions at discharge, however (153). Similarly, a meta-analysis including 13 studies (six RCTs and seven retrospective case-control studies), demonstrated that orthogeriatric care of hip fracture patients were superior in terms of functional outcomes, improved scores on cognitive tests and improved ADL levels, but showed no difference in regards to LOS or new nursing home admissions (154). A meta-analysis from 2021 by Van Heghe et al., however, demonstrated no consistent effect of orthogeriatric care on functional outcomes, but did find a lower risk of in-hospital mortality, 1-year mortality and delirium and reduced LOS (50).

In the studies that have compared different orthogeriatric models, especially the studies comparing a version of an orthopedic ward with geriatric consultant service to a version of integrated care, some have shown a positive effect on time to surgery (110, 117), LOS (110, 117) and mortality (107, 109, 110) in favor of the integrated care model. Still others show no difference in LOS and time to surgery (109), or in mortality (116, 117). There is only one study comparing the orthopedic ward with geriatric consultant service to orthogeriatric care given in a geriatric ward (132). They found longer LOS, more postoperative complications and higher 1- year mortality rate in the patients admitted to a geriatric ward (132). This is could be explained by selection bias due to the physician in the emergency department having a tendency to direct older, more cognitively and functionally impaired patients with more comorbidities and polypharmacy to the geriatric ward (132). Despite the higher complexity of the patients in the intervention group rehabilitation improvement and length of rehabilitation LOS were similar in both groups (132). Lastly, one study compared patients admitted to an orthopedic ward with geriatric consultant service upon request to patients admitted to an orthopedic ward with daily geriatric consultant service (137). They found reduced LOS and more patients were discharged to their own home, but no reduction in time to surgery, mortality, perioperative complications or increase in independence of walking at discharge (137). Due to the heterogeneity between studies in study design, outcome measures and approach to organizing the orthogeriatric care, it is difficult to conclude which orthogeriatric model is superior. Some studies implement few elements to their interventions, whilst others implement many, and there are few studies comparing different orthogeriatric models to each other.

Despite the lack of evidence for which orthogeriatric model is most beneficial for patients with a hip fracture, the overall consensus in the literature is that an orthogeriatric approach in the treatment of a hip fracture is beneficial, which is supported by several systematic reviews and meta-analyses in recent years (50, 153-155). The notion that there is a general consensus for the treatment of hip fracture patients with a multidisciplinary approach is further supported by a general call to action initiated by the Fragility Fracture Network in 2016 (156). In this call to action, which is endorsed by 81 societies, they pledge to approach fragility fractures (hereunder hip fractures) with the goal of restoring function and preventing subsequent falls by improving and intensifying the efforts to manage the fragility fractures (156). Furthermore, one of the integral methods suggested for achieving this is acute multidisciplinary care – which has to be both systematically implemented and expanded to as many countries as possible (156).

1.2.3.5 Progression and trends in orthogeriatric care over time

In the studies presented above, there seems to have been some aspects that were subjected to change over time. There was a shift over time in more sophisticated models of orthogeriatric care being evaluated, especially after 2010, in which almost half of the studies evaluated model IV (integrated care). Over time, fewer studies evaluated model I (geriatric consultant service upon request), meaning that the geriatric input was incorporated in the studies at least on a daily basis, suggesting a growing importance of the geriatric skillsets in the treatment of hip fracture patients. Another important progression observed over time is the incorporation of the geriatric input and intervention perioperatively. This is a shift from the earliest studies in which the geriatric intervention would usually come in the post-operative rehabilitation phase. Furthermore, a growing number of orthogeriatric studies emerged over time from different parts of the world, especially after 2010 (with 51 studies reporting on the efficacy of orthogeriatric care), implying that the need for and use of a multidisciplinary approach in the treatment of hip fractures is increasing world-wide.

Globally, the progression of orthogeriatric care seems to be unevenly distributed, which is reflected in the studies presented in this thesis. Mainly studies on orthogeriatric care have been conducted in Europe and North-America, few studies in South-America and the Middle-East, with Asia having a few emerging countries within the literature. Over time, more countries from each part of the world have implemented and studied orthogeriatric care. Still, there seems to be an uneven distribution of orthogeriatric care in the world. In Europe most studies have been conducted in the UK, Northern and Southern Europe, with no studies reported from Eastern Europe. As for America, the main body of evidence of orthogeriatric care comes from North-America, with little to no studies conducted in Latin- and Southern-America. In the Middle-East, the Sheba model from Israel is well-known (75), and recently a study from Egypt was conducted on orthogeriatric care (139), otherwise there is little to no activity in the Middle-East. Over time, more studies have also emerged from Asia, with China, Japan and Singapore being the forerunners, while there are some studies from Australia as well. There are no studies from Africa on orthogeriatric care. The main problem with this uneven distribution is that the regions in which there is little to no reports on orthogeriatric care, are the same regions in which the sharpest increase of hip fractures are expected (47).

Most of the studies had retrospective controls and were retrospective cohorts, a smaller proportion of the studies were prospective. This changed little over time. The results can be subject to bias such as data being registered differently at different times, or development in medical and surgical care over time. Another aspect of the study design were if follow-up were offered. Follow-up either by face-to-face evaluations or by interview of patient or next of kin over telephone were only conducted in 22 of the mentioned studies across all time periods, with little differences in the proportion over time (25% in 1980-1999, 38% in 2000-2010 and 22% in 2011-present).

When it comes to outcome measures most studies included outcome measures more commonly found as register data and/or were easily obtainable during hospital stay, such as LOS, mortality, time to surgery, postoperative complications, operation rate, place of discharge and delirium. Over time, more long-term outcomes, such as ADL levels and mobility up to a year after surgery, readmission rates and cost-effectiveness were studied, but in few studies.

With the growing evidence of a positive effect from an orthogeriatric intervention, there seems to be a general understanding amongst clinicians that orthogeriatric care is of importance when treating hip fracture patients. This is reflected in the growing number of studies conducted on orthogeriatric care and in the growing proportion of studies incorporating the geriatric input on at least a daily basis. Furthermore, based on the growing evidence, more and more countries are now implementing some form of orthogeriatric care in the treatment of hip fracture patients.

1.2.4 Implementation of orthogeriatrics in Norway and the rest of the world

Organizing care of hip fracture patients based on an orthogeriatric approach is not a new concept. In fact, orthopedic surgeons and geriatricians have collaborated on this group of patients for many years in the United Kingdom, and National Guidelines for hip fracture care with an emphasis on orthogeriatric management have been developed in the United Kingdom, Australia and New Zealand (157). In England, best practice reimbursement is implemented, and treating hip fracture patients with an orthogeriatric approach achieves the highest refund (157).

With more evidence of the efficacy of orthogeriatric models on hip fractures, there has been a shift towards more countries implementing some sort of orthogeriatric management of hip fractures. In Europe, the German Trauma Society started an initiative in 2012/2013 for orthogeriatric management of hip fracture patients and established a criteria catalogue for orthogeriatric trauma centers (120), which has resulted in more German hospitals offering orthogeriatric management of hip fracture patients. In Italy and Spain as well, similar approaches have been seen (115, 117, 158). Also Asian and Middle Eastern countries, such as China, Taiwan, Singapore and Israel, are now implementing and evaluating orthogeriatrics in their hospitals.

In Norway, the effect of orthogeriatrics have been evaluated in two randomized controlled trials (RCTs), conducted at Oslo University Hospital, Ullevaal in Oslo and at St.Olavs Hospital, University hospital of Trondheim. Both studies evaluated the effect of orthogeriatric models, in which the orthogeriatric care is given in the geriatric ward and compared this to usual care in the orthopedic ward (159, 160). The orthogeriatric intervention consisted of a comprehensive geriatric assessment (CGA), interdisciplinary cooperation, a structured care pathway with check-lists and standard protocols, early mobilization and early discharge planning.

These studies have been considered as breakthroughs regarding orthogeriatrics in Norway, and provided knowledge of care for hip fracture patients in Norway. With the basis in these studies and literature reviews, Norwegian Guidelines for Interdisciplinary Care for Hip Fractures were developed in 2019, with emphasis on interdisciplinary patient management through a clinical pathway from admission to discharge (157).

The two RCTs conducted in Norway serve as the foundation for this thesis, which will be presented in more detail in the Methods section.

1.3 Actvities of Daily Living

1.3.1 Definition

Activities of Daily Living (ADL) is a term referring to fundamental skills required for being able to take care of oneself independently (161), and was first formulated in 1950 by Sidney Katz (162). ADL is an indicator of functional status, and inability in undertaking ADLs can result in dependency and poorer quality of life, and can therefore be a predictor of nursing home admission and hospitalization (161). Assessments of a patient's ability to undertake ADL are important for clinical practice, and can help aid in planning of rehabilitation, the need for assistance at home or the need for nursing home admission. Furthermore, reduction of ADL is known to increase the risk of falling (163, 164), which in turn will increase the risk of a hip fracture.

1.3.2 Instrumental and personal Activities of Daily Living

There are two categories of ADLs; pADL and iADL.

pADL are basic skills required for an individual to manage basic physical needs. This includes ambulation, feeding, dressing, personal hygiene, continence and toileting. In this study the Barthel Index of Activities of Daily Living (BADL) has been used to measure pADL.

iADL are more complex, and include activities necessary for the ability to be independent in a community, such as transportation and shopping, managing finances, shopping for and preparing meals, home maintenance, communication (telephone and mail) and managing one's medications. The Nottingham Extended Activities of Daily Living (NEADL) was used to measure iADL in this study.

Due to the higher complexity of iADL tasks, it is not unusual that patients experience deterioration in ADLs in a hierarchical manner; in which deterioration in iADLs precedes that of pADL.

1.3.3 Consequences of a hip fracture on ADL function

Older adults suffering from a hip fracture usually experience a loss of function, with more disability in both pADL and iADL (165), and a significant number of hip fracture patients do not regain their pre-fracture functional level (42). Only 40-60% of hip fracture patients recover their pre-fracture iADL function, while for the patients who were independent in pADL before the fracture, 20-60% require assistance one or two years after the fracture (40, 166). Needless to say, this could lead to an overall loss of confidence and independency (167), requiring more socioeconomic and public health resources. Furthermore, a decline in ADL is subsequently associated with negative outcomes, such as reduced quality of life and increased nursing home admissions (168).

Of the pADL activities most affected after a hip fracture are the ambulatory activities, whilst grooming, feeding and toilet training are less affected (169). In regards to iADL activities, house maintenance, meal preparation and using public transportation were most affected (169). This shows that mechanical activity is most affected after a hip fracture.

There is little research on the differences in outcomes after a hip fracture in regards to ADL, when it comes to gender and ethnicity. Sterling et al. found no difference in ADL between Caucasians and non-Caucasians, and between men and women (9).

Already before the hip fracture occurs, many older adults have started experiencing declining ADL (170). This might not only be a contributing factor to the fall itself, and the subsequent hip fracture, but also to the overall decline seen after the fracture. A hip fracture might therefore be an extension of a complex process, in which ADL is declining. Furthermore, this also implies that pre-fracture function is important for post-fracture prognosis in hip fracture patients.

1.3.4 Efficacy of orthogeriatrics on ADL

The effect of several of the orthogeriatric models on ADL in hip fracture patients have been evaluated, and is inconsistent (50). Some studies showed a beneficial effect on orthogeriatrics on ADL (29, 56, 67, 80, 86, 94, 131, 171), while others showed only a trend towards better ADL levels (5, 68), or no effect at all (57, 84, 97, 135, 156). There were only three studies investigating the effect of orthogeriatric care on both iADL and pADL (5, 29, 86), the rest only investigated the effect on pADL alone.

Two recent meta-analyses showed that CGC improved ADL compared to traditional orthopedic care (153, 154). Only RCTs were included in the meta-analyses. Mukherjee et al. only included two RCTs, both evaluating the effect of orthogeriatric care given in a geriatric ward, and found a beneficial effect on both iADL and pADL for up to 1-year after hip fracture surgery (154). Lin et al., however, included five RCTs and found similar results. Both meta-analyses only included studies that investigated the effect on pADL with BADL, or the effect on iADL on NEADL. Because of the large heterogeneity in follow-up and scales used to assess functional outcome it is difficult to perform larger meta-analyses, including more studies that evaluate different orthogeriatric care models, and subsequently draw conclusions on what the superior model might be.

Overall, few studies incorporate ADL as an outcome measure when evaluating the efficacy of orthogeriatrics. When ADL is included, usually only pADL is investigated, or it is only included as a baseline value to describe the population. This is a paradox, seeing as one of the main goals of hip fracture care is to restore pre-fracture functional levels (50).

2. Aims of the Study

The aim of this thesis as a whole was to combine data from two randomized controlled trials, in order to produce a larger and more heterogeneous database of hip fracture patients, and consequently to further investigate this population of frail hip fracture patients. Mainly, these three aims were investigated in this thesis:

I. To evaluate the effect of an orthogeriatric model delivered in acute geriatric wards in Norway on iADL and pADL in hip fracture patients (Paper I)

II. To investigate different trajectories of ADL after a hip fracture, and associated factors for belonging to such groups following distinct trajectories of ADL (Paper II)

III. To investigate differences between intracapsular and extracapsular hip fracture patients, in regards to the two populations as a whole, but also on sub-group levels based on operation method (Paper III)

3. Patients and methods

This study is based on two randomized controlled trials, conducted in Oslo (5) and Trondheim (29), Norway. Both studies aimed to investigate the effect of orthogeriatric care on hip fracture patients, compared to traditional orthopedic care, and were planned in concert to allow future pooling of data.

In both studies, randomization was carried out in the emergency department. In Oslo, it was based on computer-generated random numbers (blocks of variable and unknown size). In Trondheim, a web-based computer-generated randomization was used, where patients were randomized in a 1:1 ratio with blocks of unknown size. Participants were randomized either to a geriatric ward, where they received comprehensive geriatric care (CGC), or to an orthopedic ward for usual care.

Patients were transferred directly to their allocated ward after randomization, in which all the pre- and postoperative care was delivered. Anesthesiologic and surgical procedures were similar in both intervention and control group.

Assessments were carried out at baseline, four- and twelve-months follow-up. If the participants were unable to visit the hospitals during follow-up, study nurses would offer home-visits at their current residence for face-to-face assessments. The study nurses conducting the follow-up assessments were blinded to group-allocation. Data collection during index stay could not be blinded, due to the intervention being at ward level.

3.1 The Oslo Orthogeriatric Trial

This trial was conducted at Oslo University Hospital, Norway, and recruitment of patients lasted from September 2009 to January 2012. They included all hip fracture patients as long as the hip fracture was due to a low-energy trauma. Hip fracture patients that were moribund at admission, or had suffered a fracture due to a high-energy trauma were excluded from this trial. Both home-dwelling and nursing home patients, at all ages were included, in total 329 patients. Randomization was stratified based on whether or not the patients were admitted from a nursing home.

Pre- and postoperative treatment for patients randomized to intervention were conducted in the acute geriatric ward. The intervention consisted of CGC service, which included medication reviews, early and intensive mobilization, optimizing pre-and postoperative nutrition, and early discharge planning. An interdisciplinary team, consisting of a geriatrician, nurse, physiotherapist and occupational therapist were responsible for delivering the CGC service. They were also expected to assess newly admitted patients during their first day on the ward, and to conduct daily meetings to coordinate treatment and plan discharge. Details about the clinical routines have been published (160).

The control group were treated in the orthopedic ward, where there were no multidisciplinary meetings or geriatric assessments. However, early mobilization was routine and all hip fracture patients were seen by a physiotherapist. In addition, all patients treated in the orthopedic ward, was offered a control four months after surgery in the orthopedic outpatient clinic. There was no other intervention offered after discharge.

Cognitive function four months after surgery was the primary outcome for this study. Secondary outcomes included delirium, delirium severity, length of hospital stay (LOS), mortality, mobility, place of residence, iADL and pADL, and weight changes.
There was no impact of intervention on the primary outcome, and delirium rates and severity were high in both groups. However, better mobility measured by the Short Performance Physical Battery (SPPB) was found in home-dwelling patients.

3.2 The Trondheim Hip Fracture Trial

The Trondheim Hip fracture Trial was conducted in St. Olav University Hospital in Trondheim, Norway. Recruitment of patients lasted from April 2008 to December 2010. In this trial only home-dwelling hip fracture patients aged 70 years or above, who had been able to walk 10 meters or more before the fracture were included, in total 397 patients. Patients that were moribund or living in a permanent nursing home at admission, as well as patients with pathological fractures or multiple traumas were excluded.

Intervention with CGC treatment took place in the geriatric ward, both pre- and postoperatively. Comprehensive medical assessment and treatment, early rehabilitation and early planning of discharge was part of the CGC service. For the patients discharged directly home, individualized rehabilitation plans were developed. Details about the clinical routines have been published (159).

For both the intervention and control groups patients received care and physiotherapy, in accordance with guidelines. If needed, a geriatrician assessed patients receiving orthopedic care or an orthopedic surgeon assessed patients receiving CGC upon request. The primary health care services were responsible for follow-up after discharge from hospital in both patient groups. There was no follow-up after discharge offered routinely.

The primary outcome was mobility after four months, measured by the SPPB. Secondary outcomes included iADL, pADL, cognition, quality of life, fear of falling, depression, gait control and daily physical activity. The study reports a positive effect of intervention on SPPB, and also on several of the secondary outcomes (iADL, pADL, fear of falling, quality of life, gait control and daily physical activity).

3.3 The OslO and Trondheim HIP Fracture Trial (TOOHIP)

The Oslo Orthogeriatrics Trial and The Trondheim Hip Fracture Trial were planned in concert, for the possibility of future pooling of data. Thus, similar design and outcomes were chosen for both trials, as described in their protocols (159, 160). The goal was to combine the two trials to make a larger and more heterogeneous database on hip fracture patients, for the opportunity for more precise estimates on outcomes and generalizability.

Merging of the two trials started in October 2016, as a study conducted as a part of the Norwegian Medical Student Research Program (Forskerlinjen). Later this work was continued as part of the Ph.D.-program at the University of Oslo. The merging of the two databases was conducted in IBM SPSS Statistics 22-25, where similar outcomes from the two trials were combined and inserted in the new database, named The OslO and Trondheim Hip Fracture Trial database (TOOHIP). A log of the commands and procedures used were kept and updated during the merging process. All available outcomes that were similar or identical in the two trials for baseline, four- and 12-months follow-up were added to TOOHIP.

A total of 726 patients were included in the combined database, see Figure 3.

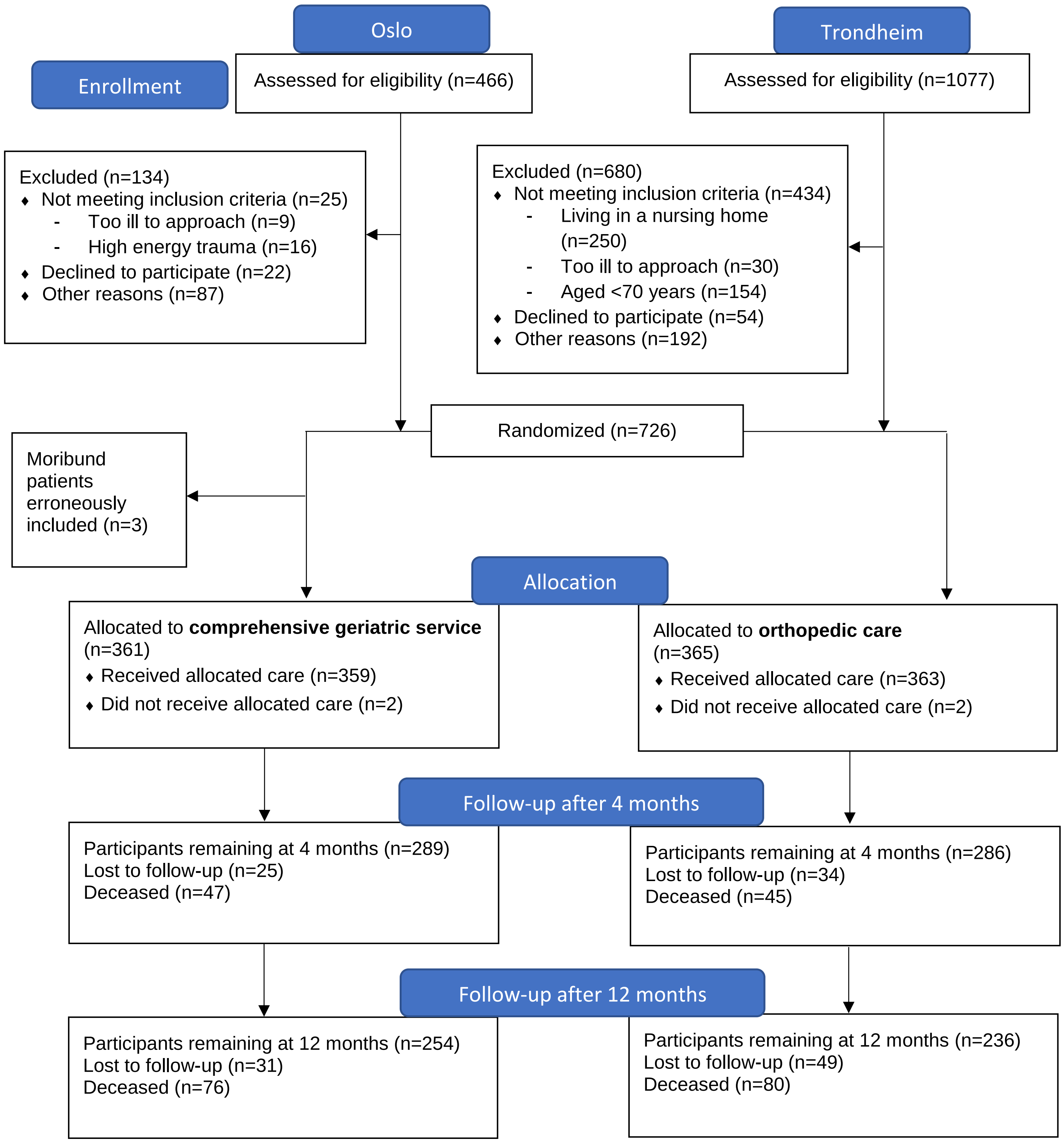

Figure 3 Flow Chart of the inclusion for each of the two trials, and combining of the databases.

3.4 Assessments

Assessments and data collections were carried out at baseline, and at four- and 12-months after surgery. This section gives a description of the assessments used for the work in this thesis.

3.4.1 Baseline registration

3.4.1.1 American Society of Anesthesiologist (ASA) Scale

The ASA scale is a scale reflecting a patient's physical status and health prior to possible surgery (172). Patients are categories in to one of five categories based on an evaluation conducted by a clinician. ASA I – A healthy patient, ASA II – A patient with mild systemic disease, ASA III – A patient with severe systemic disease, ASA IV – A patient with severe systemic disease that is a constant threat to life, and ASA V – A moribund patient who is not expected to survive without the operation.

In this study the ASA scale, in conjunction with the Charlson Comorbidity Index (CCI), were used to assess comorbidity in patients at baseline.

3.4.1.2 Charlson Comorbidity Index (CCI)

The CCI is a 19-item scale of comorbid conditions, developed for the assessment of comorbidity in patients, and for prediction of death within one year after hospital admission (173). A higher score is given with more comorbid conditions (range 0-19), and consequently a higher risk of death is associated with the accumulation of comorbid diseases.

3.4.1.3 Type of fracture

All fractures were registered according to the ICD10 classification system, and were all coded as proximal femoral fractures. The registered fractures are coded based on sub-groups of proximal femoral fractures as follows: femoral neck fractures (S72.0), per-trochanteric fractures (S72.1) and sub-trochanteric fractures (S72.2). For this study the fractures are dichotomized into intracapsular fractures, which all include femoral neck fractures, and extracapsular fractures, which include all per- and sub-trochanteric fractures.

3.4.1.4 Surgical procedures and operative data

Operative data included injury site (indoor vs. outdoor), side of fracture (left vs. right), waiting time to operation (hours from admission to start of anesthesia), duration of operation (from start to stop of anesthesia), type of anesthesia (local vs. regional) and operation method (hemiarthroplasty (HA), internal fixation, Girdlestone, total hip arthroplasty (THA) or not operated).

3.4.1.5 Demographic and descriptive data

Demographic data such as age, gender and place of residence were included in the database, as well as descriptive data such as Body mass index and depressive symptoms.

Depressive symptoms were assessed differently in Oslo and Trondheim. The Cornell Scale of Depression in Dementia (CSDD) (174, 175), were used in Oslo. This is a 19-item instrument, administered by a clinician, in which both the patient and a caretaker is interviewed. This scale was developed for patients with dementia, but has been validated for both patients with and without dementia (174, 175). Each item is rated for severity on a scale (0=absent, 1=mild or intermittent, 2=severe), the scores are then added and a higher score is indicative of more severe depression (range 0-38).

In Trondheim the Geriatric Depression Scale 15 (GDS-15) (176) were used to assess depression in patients. The GDS-15 is a 15-item self-evaluation instrument, reflecting depressive symptoms experienced by the patient the last week prior to the test being administered. There are 15-items answered yes/no, in which different answers will give one point for each of the items. Also for this instrument, a higher score is indicative of more severe depressive symptoms (range 0-15).

For this study we merged the two scales by using a cut-off for each scale (CSDD cut-off $\geq$8 (174, 175), GDS-15 cut-off $\geq$6 (177)) based on studies on validation (174, 177), and dichotomized the outcome of depression into yes or no for depressive symptoms.

All measures were collected at baseline, and at four- and 12-months follow-up.

3.4.2 Activities of Daily Living (ADL)

3.5.2.1 Barthel Activities of Daily Living Index (BADL)

The BADL was used to measure pADL (178). This is a 10-item questionnaire, with each item being scored between 0-3 points, giving a maximum of 20 points on the scale. A higher score is indicative of more independence in taking on pADL. The items are as follows: eating, bathing/showering, personal hygiene, dressing, bowel control, bladder control, toilet visits, transfer between bed and chair, mobility and stair walking.

The value was obtained by proxy-interview, or a combination of proxy-interview and patient interview at follow-up. The proxy was asked to describe and fill out the questionnaire based on the previous 14 days. Thus, the baseline value of the BADL in this study is a reflection of the pre-fracture pADL.

BADL is well established and used in both research and clinical practice. Initially developed for stroke patients, it has later been validated for geriatric patients as well (179). It can be used both as a questionnaire and as an interview, and it can be used either face to face or over telephone (179). Even though BADL has been found to have good sensitivity to change over time, it may have a floor effect in very frail populations and a ceiling effect in populations with higher function (180).

3.4.2.2 Nottingham Extended Activities of Daily Living (NEADL)

IADL was measured by NEADL (181). The NEADL is a 22-item scale, each item scored between 0-3, with a maximum score of 66 points. A higher score is indicative or higher independency in taking on iADL. NEADL has four categories: mobility (six items), kitchen activities (five items), domestics (five items) and leisure time (six items).

A proxy was interviewed based on the previous 14 days for this value to be obtained. The baseline value of the NEADL is therefore a reflection of the patients' pre-fracture iADL. At follow-up, the value was obtained by a combination of proxy-interview and patient interview.

NEADL have been used in several hip fracture studies to measure iADL. It can have a ceiling-effect in populations with higher functional levels (182).

3.4.3 Physical function

3.5.3.1 Short Physical Performance Battery (SPPB)

The SPPB was used as a measure of mobility (183). It consists of three domains – balance, gait speed and sit to stand. Each domain is scored between 0-4 points, for a total of maximum 12 points. A higher score is indicative of better mobility, and a difference of 0.5 is considered clinically relevant. The SPPB was tested at the follow-ups.

3.4.3.2 Gait speed

The gait speed was extracted from the SPPB and used as a separate measure for paper III. It was reported as meters per second, and is a measure of how fast the patient was able to walk 4 meters. It was tested two times for each follow-up, and the best gait speed is reported.

3.4.3.3 Hand grip strength

Hand grip strength was measured at baseline, and at four- and 12-months follow-up. It was measured using a hand dynamometer (JAMAR, Germany), and measured for three repetitions each examination. It was measured daily during hospital stay, in which the highest value was used for our analyses.

3.4.4 Cognition

3.4.4.1 Clinical Dementia Rating Scale (CDR)

Cognitive function was measured by CDR, which is a questionnaire consisting of six domains (184). The six domains are memory, orientation, judgement, community affairs, home and hobbies and personal care. Each domain can be scored from 0 to 3, in which a higher score is indicative of more impairment, giving a maximum total score of 18. This summation of the scores from all the domains are called the CDR sum of boxes, which is the score used in this study. CDR was obtained from all time points.

3.4.4.2 Mini Mental Status Examination (MMSE)

Another measure of cognitive function used in this study was the MMSE (185), which was obtained from both the follow-up time points. MMSE is a performance-based screening tool for cognitive impairment, and consists of 20 items across five categories. The five categories are orientation (10 items), registration (1 item), calculation and attention (1 item), recall (1 item) and language and constructional praxis (7 items). A maximum of 30 points is obtainable, in which a higher score is indicative of better cognitive function.

3.4.5 Mortality

Mortality was registered as in-hospital mortality, and mortality at four months and 12 months.

3.5 Statistics

Statistical analyses were carried out in collaboration with one or more statisticians for paper I and II. For paper I, Stian Lydersen (SL) and Eva Skovlund (ES) took part in the planning of the analyses. Furthermore, SL educated and trained me in linear mixed models, and helped in writing of the statistical analysis plan (SAP). The final analyses were carried out by me, after training.
For paper II, Jūratė Šaltytė Benth (JSB) carried out the growth mixture modeling and multinomial regression analyses. All other analyses were done by me. For paper III, all analyses were carried out by me.

All statistical analyses were carried out using IBM SPSS Statistics versions 22-28. A two-sided p-value below 0.05 was considered statistically significant.

3.5.1 Comparisons and significance testing (Paper I-III)

For papers I-III, in comparisons between groups, Mann-Whitney test were used for continuous variables and Chi-square tests were used for categorical variables.

Specifically for paper III, we wanted to compare postoperative outcomes in patients with different hip fracture types. We compared patients with an extracapsular hip fracture with all intracapsular hip fracture patients, and patients with and extracapsular hip fracture to patients with an intracapsular fracture operated with hemiarthroplasty (HA).

3.5.2 Mixed models (Paper I)

Prior to any analyses being made with the mixed models, a statistical analysis plan was completed and published online (186). Linear mixed models was used for analyses of repeated measures, which offers several strength and advantages. It is considered to handle missing data appropriately, especially variables missing at random (MAR), in large study populations with data collected over multiple time-points (187). Furthermore, mixed models allow for more flexible modelling and allow for more subjects to be included in analysis due to its ability to include participants with missing values (188).

In paper I we wanted to assess the efficacy of intervention on iADL and pADL. The primary efficacy analysis was conducted using linear mixed models, in which NEADL was the dependent variable. We chose patient as random factor, and time point (baseline, four months and 12 months) as fixed factor. Treatment group, site (Oslo vs. Trondheim), age, sex, fracture type (extracapsular versus intracapsular), home-dwelling versus nursing home, and the interaction between time points after inclusion and treatment group were chosen as covariates. For the efficacy analysis on the secondary outcome of pADL, a similar model was used, with BADL score as the dependent variable.

Covariates were chosen based on clinical judgement after discussion between doctors and statisticians (SL and ES), and were believed to have an impact on outcome (188).

To use and include as many participants as possible, missing items for NEADL and BADL were imputed. This was carried out by imputing the mean score for the remaining items that were answered, if at least 80% or more of the items on each scale were answered.

3.5.3 Growth mixture modeling (Paper II)

Growth mixture modeling is suitable for identifying groups of patients based on their individual profiles (189). Several statistical criteria are used for this approach. Bayes Information Criterion is used to determine the number of groups that best cover the heterogeneity in participants' profiles, where a smaller value correlates to a better model. Furthermore, an average within-group probability of at least 0.80, reasonable group sizes, and non-overlapping 95% confidence intervals (CIs) of the group trajectories were required.

In paper II we wanted to explore if our dataset yielded groups of patients following distinct trajectories of ADL after a hip fracture. Growth mixture models were therefore used to identify possible homogenous groups of participants following distinct trajectories in NEADL and BADL. Analysis was carried out by a statistician (JSB), and models were assessed for criteria in collaboration with the statistician (JSB). All patients completing at least baseline testing were included in the analyses.

3.5.4 Multiple nominal regression (Paper II)

Multiple nominal regression, also sometimes referred to as multinomial regression, is used when assessing categorical dependent variables that are non-ordinal and for variables with more than two categories (190, 191).

Multiple nominal regression models were used in paper II, to assess which baseline characteristics were associated with belonging to the different groups following the distinct trajectories. The largest groups were used as reference for all models. Cluster effect was assessed by intra-class correlation coefficient, seeing as the data was collected from two different hospitals. In addition, the variable for care models (CGC or OC) was treated as a control variable.

The analysis included patients with no missing values on considered characteristics. Characteristics considered were sex, age, type of fracture (intracapsular vs. extracapsular), preoperative waiting time, ASA score (1 or 2 vs. 3 or more) and CDR sum of boxes.

3.5.5 Sensitivity analyses (Paper I and III)

Sensitivity analysis is used to evaluate whether or not a change in variables have an impact on results in the analysis. This can be done to evaluate the robustness of the results, for example by doing the analysis with and without outliers. The same methodology must be applied for both the sensitivity analysis and the regular analysis. In both paper I and III we performed sensitivity analysis by excluding the patients admitted from a nursing home, to see if this had an impact on our results. For paper I this was done with mixed models, and for paper III this was done by bivariate analysis.

3.6 Literature

To gain an overview of the literature concerning orthogeriatric care, an advanced search was conducted in PubMed with the following search phrase:

“("Femoral Fractures"[Majr] OR ((Femoral [Title] OR Femur[Title] OR Hip[Title]) AND (Fracture[Title] OR fractures[Title]))) AND (Combined Modality Therapy [MeSH] OR Comprehensive health care [MeSH] OR interdisciplinary communication [Majr] OR Geriatric assessment [Majr] OR Orthogeriatric[Title] OR Ortho-geriatric*[Title] OR comprehensive [Title] OR multi-modal[Title] OR multimodal[Title]) AND (English[lang] OR Norwegian[lang])”*

This search phrase yielded 1343 search results in March 2023, and included articles published between July 1967 and March 2023. Articles were then selected if their title seemed relevant, which resulted in 443 articles. Further screening of abstracts and the article text in full aided in grouping of 112 relevant articles in orthogeriatric care into the four categories presented in section 1.2, see Figure 4. Articles were included if they reported an effect of orthogeriatric care and if there was a defined orthogeriatric model.

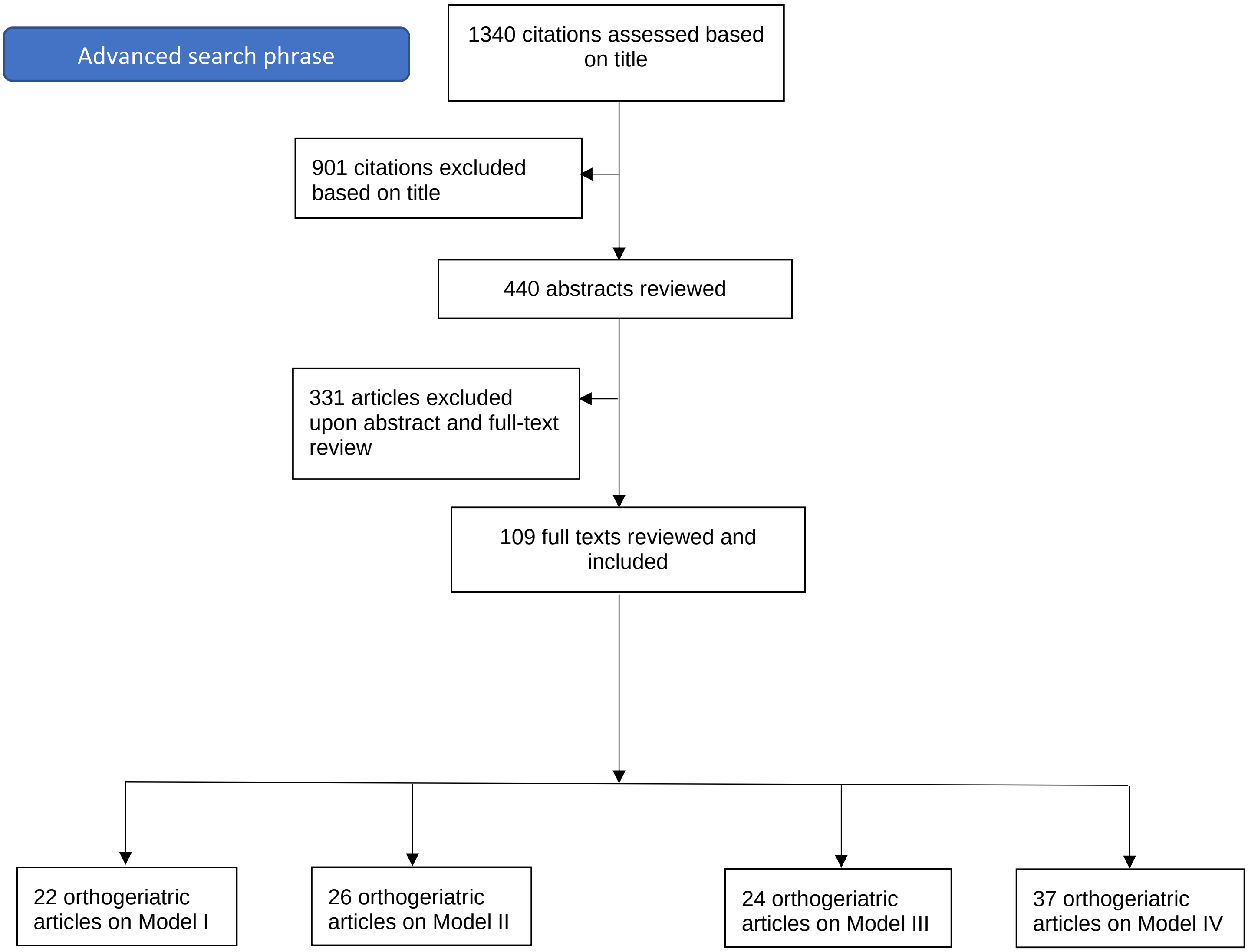

Figure 4 Flow Chart of the literature review and inclusion

3.7 Ethical consideration

Both studies were conducted in accordance with the Declaration of Helsinki. All cognitively unimpaired patients gave their informed written consent to be included in both the trials. For the cognitively impaired patients a proxy gave informed written consent to be included in the study before participation in both trials. The combining of the two trials to a joint database had no impact on the patients or the care given, nor was there any additional data collected. Both trials were approved by a Regional Ethical Committee for Ethics before data collection.

The Oslo Orthogeriatric Trial was registered with ClinicalTrials.gov (NCT01009268), and approved by the Regional Committee for Ethics in Medical Research in South East of Norway (REK 2009/450). The Trondheim Hip Fracture Trial was registered with ClinicalTrials.gov (NCT00667914), and approved by the Regional Committee for Ethics in Medical Research in Central Norway (REK4.2008.335). The Regional Committee for Ethics in Medical Research in South East of Norway and the Data Protection Officer at both hospitals approved merging of data from the two separate trials.

4. Main results

In total, 726 patients were included in the combined database, in which 329 patients were included from Oslo and 397 patients were included from Trondheim, see Figure 1 of Flow Chart. Of the 726 patients included, 365 patients were randomized to the control group and received traditional OC care, and 361 patients were randomized to intervention with CGC care. Baseline characteristics did not differ between groups.

For the whole population, mean age was 83.0 years, 74.7% were women, 60.1% had an intracapsular fracture and 14.0% were living in a nursing home at admission. All patients admitted from a nursing home were included from the Oslo Orthogeriatric Trial. The groups were similar at baseline for iADL and pADL, measured by mean NEADL (37.1 in the CGC group vs. 37.5 in the OC group) and mean BADL (17.2 in the CGC group vs. 17.4 in the OC group), respectively.

4.1 The effect of orthogeriatrics on Activities of Daily Living (ADL) (Paper I)

Results: The CGC group had better iADL compared to the OC group, at four months follow-up, measured by mean NEADL score, with a between-group difference of 3.56 points (CI 0.93 to 6.20, p=0.008). At twelve month follow-up, the between-group difference was 4.28 points (CI 1.57 to 7.00, p=0.002) in favor of the CGC group.

For pADL, measured by mean BADL score, the between-group difference was 0.34 (CI 0.25 to 0.94, p=0.26) at 4 month follow-up, and 0.68 (CI 0.05 to 1.31, p=0.0034) at 12 month follow-up in favor of the CGC group.

The effect of intervention on both iADL and pADL remained clinically relevant in all time points after sensitivity analysis, excluding patients admitted from a nursing home.

The LOS was longer in the CGC group compared to the OC group (mean 12.8 vs. 9.8 days, p<0.001), but there were no difference between groups in regards to preoperative waiting time, in-hospital mortality, cumulative mortality at four- and 12-months follow-up, nor in new nursing home admissions.

Conclusion: Comprehensive geriatric care has a positive effect on both iADL and pADL in hip fracture patients up to one year after hip fracture surgery. The effect is stronger in home-dwelling patients.

4.2 Different trajectories of ADL after a hip fracture (Paper II)

Results: Four different groups of patients following distinct trajectories for both iADL and pADL were identified with growth mixture modeling, see Figure 5. Average group probabilities were all above 0.8 and 95% Cis non-overlapping, implying homogenous groups.

For iADL, especially one group, the *'Poor function'* (n=143, 20.3%) group, showed relatively high baseline NEADL scores, but declined steeply the first four months after hip fracture. For pADL, two groups, '*Poor function'* (n=154, 21.7%) and *'Very poor function'* (n=38, 5.4%), had a similar steep decline the first four months after hip fracture. Similar for all trajectories for both iADL and pADL, were that they were non-linear and declined significantly over 12 months (all p's <0.001 and <0.01, respectively).

For both groups of '*Poor function'* higher age and higher ASA score were more common, whilst in the groups belonging to the *'Very poor function'* trajectory, being admitted from a nursing home, a high ASA score and an intracapsular fracture were more common.

Results of the multiple nominal regression showed that younger age, an ASA score of 1 or 2, and lower CDR scores were associated with belonging to groups with higher ADL and better trajectories.

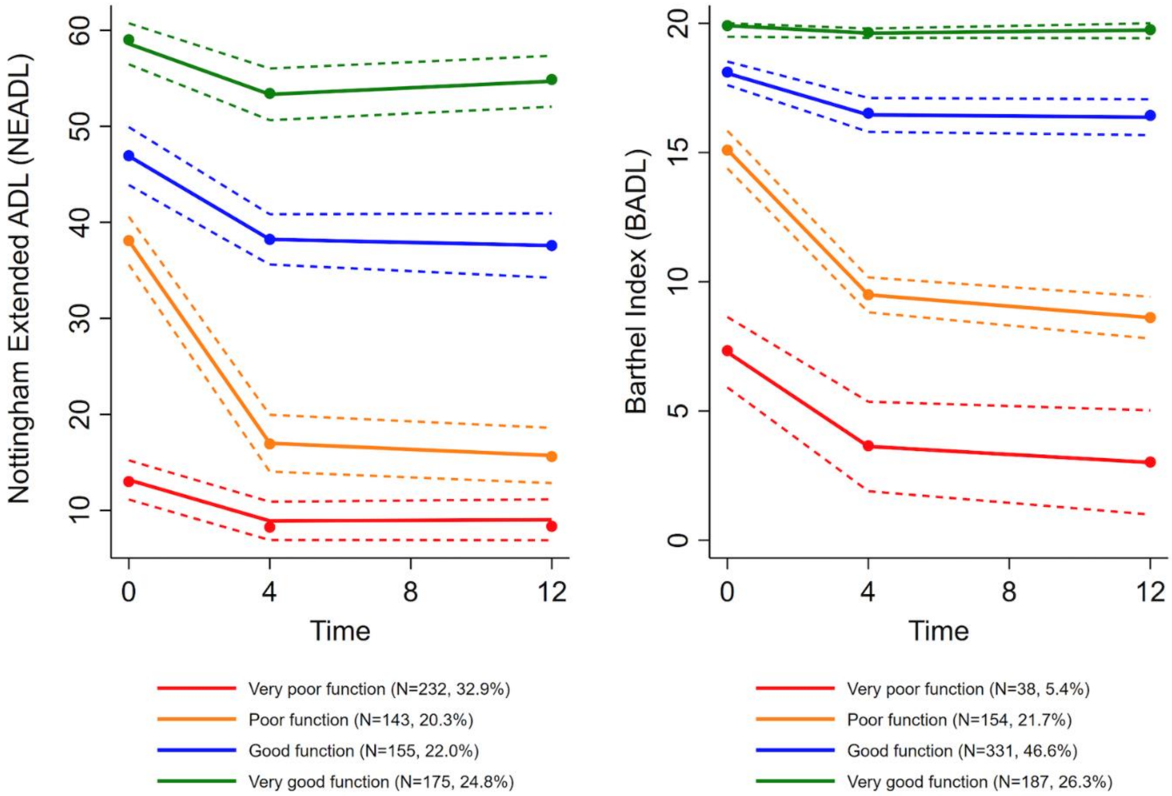

Figure 5 Growth mixture models for instrumental Activities of Daily Living (NEADL) and personal Activities of Daily Living (BADL) with corresponding confidence intervals

Conclusion: Four groups of hip fracture patients following distinct trajectories for each iADL and pADL was identified. There was no functional recovery between four and 12 months in any group, and no group regained their pre-fracture ADL levels. In addition, there was one group for each iADL and pADL with relatively high function before the fracture that had a steep decline the first four months after the fracture. This group is a clinically interesting and relevant group, and might show a potential for rehabilitation. Future studies should investigate this group further.

Similar for all trajectories were that younger age, lower ASA score and better cognitive function at baseline was associated with belonging to a group with better ADL.

4.3 Long- and short -term outcomes in extracapsular vs. intracapsular fractures (Paper III)

Results: For the primary analysis, 711 patients were included; 283 patients with an extracapsular fracture and 428 patients with an intracapsular fracture. There was no difference between the extracapsular hip fracture and intracapsular hip fracture groups in regards to waiting time for surgery or LOS.

The intracapsular fracture patients had better SPPB (5.0 vs 4.0, p=0.007), pADL (17.0 vs. 16.0, p=0.007) and iADL (32.5 vs. 28.0, p=0.049) at four-month follow-up, but this did not persist at 12 months follow-up.

546 patients 70 years or older were included in the sub-group analysis; 268 patients with an extracapsular fracture and 278 with an intracapsular fracture operated with HA. There were no difference in waiting time for surgery or LOS when comparing the extracapsular hip fracture patients with the intracapsular hip fracture patients operated with HA. The patients with an intracapsular fracture (operated with HA) had better median SPPB scores (4.0 vs. 3.0, p=0.014) and better median pADL scores (17.0 vs. 16.0, p=0.014) at four-month follow-up. There was no difference between the groups at 12 months follow-up.

Conclusion: When comparing the intracapsular fracture patients with the extracapsular fracture patients groups as a whole, there were no differences in mortality rate, waiting time for surgery, LOS or new nursing home admissions. For both this comparison and the sub-group analysis comparing the extracapsular hip fracture group with the intracapsular hip fracture operated with HA group, there was a difference in SPPB and ADL at four months follow-up, which did not persist 12 months after hip fracture. This might indicate a faster initial rehabilitation after HA. There were no other major differences between the groups, and the groups were similar at baseline.

5. Discussion

5.1 The effect of orthogeriatrics on ADL (Paper I)

We found that CGC in a geriatric ward had a positive effect on ADL in hip fracture patients, compared to traditional OC. For iADL the difference in NEADL score was 3.56 and 4.28 points better for CGC than for OC at four- and 12-months, respectively. There was also a beneficial effect in pADL for CGC compared to OC, with a better BADL score of 0.34 and 0.68 points at four- and 12-months, respectively. The effect was not statistically significant for pADL at four months.

The effect of the intervention on ADL was stronger in home-dwelling hip fracture patients, in which patients showed significantly better functional gain in both iADL (between-group difference in NEADL score of 4.56 points at four months and 5.42 points at 12-months) and pADL (between-group difference in BADL score of 0.67 points at four months and 0.97 points at 12-months) compared to hip fracture patients receiving OC.

A 2.4 point difference in NEADL score is considered to be clinically significant (192), whilst one point in BADL score is the difference between being able to independently undertake basic ADL functions (e.g. walking, feeding and toilet use). We therefore believe the effect of the orthogeriatric intervention in this study to be clinically significant. The small effect sizes in BADL could be due to a ceiling-effect in the more fit patients and/or a floor-effect in the frailest patients, thus showing a relatively small effect on group level.

There are only a few studies conducted, that evaluates the effect of an orthogeriatric model on ADL. While some studies showed a beneficial effect (29, 56, 67, 80, 86, 94, 131, 171), others showed only a trend towards better ADL levels (5, 68), or no effect at all (57, 84, 97, 135). Furthermore, only three of the studies included iADL and pADL (5, 29, 86), the rest only investigated the effect on pADL alone. To our knowledge, only two other studies investigating the effect of orthogeriatric care on ADL was conducted in a geriatric ward. Adunsky et al. conducted a quasi-RCT, and showed that patients treated in the intervention-arm had almost a two-fold chance of successful rehabilitation, defined as “more than 50% increase in relative functional gain” (67). Functional status was measured by motor functional independence measure, and it was only assessed during hospital admissions (67). Yet, another RCT from Sweden, found that significantly more patients allocated to the intervention had regained their independence in pADL and iADL, measured by the Katz Index of

Independence in ADL, four and 12-months after surgery (86). Our findings are in line with these studies.

There are several aspects of orthogeriatric care that might have directly or indirectly influenced ADL levels, in both the studies included in TOOHIP. As a part of the intervention, there was a focus on early discharge planning, early and intensive mobilization overseen by physiotherapists, in addition to several elements aiming to improve health (159, 160). Focus on optimization of pain relief, nutrition and comorbid conditions might have allowed for better general health and more activity in the days after surgery, thus improving rehabilitation. All members of the orthogeriatric team (geriatricians, nurses, physiotherapists and occupational therapists) had regular meetings in which they discussed patients' progress, coordinated treatment and planned discharge. The increase in pADL and iADL levels seen in the intervention group, compared to traditional care, can be a result of these interventions. The focus on early mobilization, with training in pADL and walking in staircase, could have contributed to the rehabilitation and the increase seen in ADL. In addition, early discharge planning could have initiated several processes in which the patients would have been prepared for ADL activities at home (for instance training in pADL). Especially, if the goal was to return to the same residence as before the fracture, that could have served as motivation for the patient and a positive influence on ADLs. Furthermore, seeing as three of the ten items of BADL and six of the twenty-two items of NEADL measure aspects of mobility, one could postulate that the increase in ADL levels could be a direct result of the increase in mobility (measured by SPPB) shown in both studies (5, 29). Maintaining good mobility is essential for undertaking pADL and iADL, as previously mentioned.

When excluding the patients admitted from a nursing home at admission, we saw a stronger effect of the intervention on both iADL and pADL. This suggests that the home-dwelling hip fracture patients had greater benefit of the intervention. A possible explanation for this is that nursing home patients are frailer than home-dwellers, and in that have lost more function prior to the fracture. In turn, this might reduce the potential for recovery or further reduction of functional decline. The Trondheim Hip Fracture Trial conducted sub-group analyses to find potential sub-groups of hip fracture patients that benefit most of the intervention. The analysis showed that younger patients with higher pre-fracture iADL had the most pronounced effect of the intervention (145). An interpretation of this can be that the more fit patients have more functional capacity, and therefore a larger potential for functional decline after a hip fracture, leading to a greater potential for functional rehabilitation. This does not, however, imply that the frailer patients do not benefit of an orthogeriatric intervention, but it might suggest that other parameters might be better to measure the effect (such as quality of life). Furthermore, it suggests that the population of hip fracture patients are heterogeneous, wherein there are different groups of patients with different rehabilitation needs.

5.2 Different trajectories of ADL after a hip fracture (Paper II)

In paper II we found four different groups of patients following distinct trajectories for both iADL and pADL. No group regained their pre-fracture ADL levels, and the decline in function was steepest the first four months after hip fracture. Especially the '*Poor function'* group for both iADL and pADL, showed relatively high baseline ADL levels, but declined steeply the first four months after the fracture. Younger age, an ASA score of 1 or 2 and better cognitive function at baseline were associated with belonging to groups with higher ADL levels and better trajectories.

The decline in ADL levels were steepest the first four months after surgery, and all trajectories continued to decline further after that, but less steeply. If this is a consequence of rehabilitation being too short or not intensive enough or if it is a result of the patients reaching their maximum rehabilitation potential remains unanswered (193). There are few other studies investigating functional trajectories in hip fracture patients. A prospective cohort study from the Netherlands found that after a hip fracture there was an increase in disability after three months compared to pre-fracture status, based on the Katz ADL Index, with 80% of patients not returning to their pre-fracture functional levels at one year after hip fracture surgery (194). This is in line with our findings, showing that most hip fracture patients do not regain their pre-fracture function one year after surgery.

Furthermore, we identified four distinct groups following different trajectories for each pADL and iADL. These groups were homogenous and non-overlapping, implying that they represent different groups of hip fracture patients. The population of hip fracture patients are heterogeneous, and identifying different sub-groups within this population can aid in discharge and resource planning, prognostication and individualizing health care. Patients within these different groups might have different rehabilitation potential, and therefore a need for a more individualized rehabilitation approach. What kind of rehabilitation and how long and intensive it should be for each group, should be studied in future research.

For both pADL and iADL the group of patients following the *'Poor function'* trajectory had a relatively high baseline ADL function that steeply declined. The decline was steepest the first four months after surgery, and persisted for one year after. The majority of these patients were home-dwellers (98.6% and 66.2% of the patients following the *'Poor function'* trajectory for iADL and pADL, respectively), and it was more common to have higher age and an ASA score of 3 or more in these groups. This group is of particular interest, and might represent a group of patients in which there lies a potential for improved acute care and rehabilitation. Because these patients are mostly home dwelling and have relatively high ADL levels before the fracture they should theoretically be less frail, but their high ASA score at admission could reflect acute disease or frailty, occurring either before or during the hip fracture. Optimizing acute care and correcting for comorbidities, in addition to rehabilitation, can prevent the decline in ADL levels. On the other hand, the steep ADL decline in this group can be a result of the high ASA score observed – either by reflecting a disease that contributes to the fall and fracture or by reflecting an innate frailty that subsequently result in worse ADL recovery. The mechanisms behind this are yet unknown and future research should aim to increase the knowledge about this group of hip fracture patients and what acute treatment and rehabilitation to offer them.

Interestingly, even the groups of patients following the *'Very good function'* trajectories for both iADL and pADL, lost function and did not regain their pre-fracture function over the following year after the hip fracture. These patients were younger, none was admitted from a nursing home and the majority of them had an ASA score of 1 or 2. The fact that even the fittest hip fracture patients are affected after the fracture in terms of ADL could either be a reflection of the frailty in this group, how devastating a hip fracture is or both. A systematic review focusing on the long-term disabilities after a hip fracture compared hip fracture patients to a non-fracture group of the same age and found that hip fracture patients are less independent in ADL than the non-fracture group, and that the level of independence is associated with pre-fracture function (40). Even the patients that were independent in ADL pre-fracture 20-60 % required assistance for various tasks 1 and 2 years after fracture (40). Because the functional recovery after a hip fracture is associated with pre-fracture function (145, 195-198), the patients in the groups following the *'Very good function'* trajectories should theoretically have a good recovery prognosis, and even though their ADL levels one year after surgery were not low, they still did not reach their pre-fracture functional levels. Future research should focus on if it is possible to regain pre-fracture functional levels after a hip fracture, and what intervention or rehabilitation can achieve this.

For both groups of '*Poor function'* higher age and higher ASA score were more common, whilst in the groups belonging to the *'Very poor function'* trajectory, being admitted from a nursing home, a high ASA score and an intracapsular fracture were more common. Additionally, multinomial regression showed that a higher CDR score was more likely in these groups. Approximately half of the study population were in the two lowest trajectories of iADL, with 30% of the patients being in the lowest group in which iADL was already poor before the fracture. This can be an illustration of the low pre-fracture function as a contributing factor to the fall and subsequent hip fracture, and consequently the significant functional decline postoperatively. This is in alignment with literature finding that pre-fracture function is an important factor for post-fracture functional recovery (145, 195-198). Furthermore, due to the low pre-fracture function in this group it is not unreasonable to speculate that they have little to no functional rehabilitation potential or capacity, and that the overall decline after hip fracture is not surprising. Cognition is also an important factor in rehabilitation. A study found that after a hip fracture, patients with more cognitive impairment, measured as lower scores on MMSE, were more likely to be dependent in pADL, while the patients with better cognition had better recovery and less dependency in pADL (199). This is in alignment with our findings that the trajectories with poorer outcomes were more likely to have higher CDR scores.

The four trajectories for each of the two ADL outcomes found in this study can be an aid in resource planning and prognostication, as they represent different hip fracture patients with different needs. The *'Poor function'* trajectory represents a group at risk for massive decline after hip fracture and the *'Very Poor function'* trajectory represents the frailest patients with little to no rehabilitation capacity. An observational study from Norway found that hip fracture patients may be divided into three groups based on their risk profiles; well-functioning, intermediate-functioning and low-functioning (200). While the well-functioning group are the youngest and the fittest, the intermediate-functioning group are at most risk of institutionalization and may benefit from careful discharge planning and rehabilitation after discharge (200). The low-functioning group is the frailest and may benefit the least from an intensive rehabilitation program (200). This is in line with our findings, suggesting that there are four groups of hip fracture patients who will most likely benefit from different care pathways and rehabilitation after a hip fracture, and who have different prognosis.

5.3 Comparison of extracapsular vs. intracapsular fractures (Paper III)

In the primary analysis, we found no difference between the patients with an extracapsular hip fracture and intracapsular hip fracture in waiting time for surgery or LOS. However, patients with an intracapsular fracture had better SPPB (5.0 vs 4.0, p=0.007), pADL (17.0 vs. 16.0, p=0.007) and iADL (32.5 vs. 28.0, p=0.049) at four month follow-up, that did not persist at 12 months follow-up.

For the sub-group analyses, patients with an intracapsular fracture (operated with HA) had better median SPPB scores (4.0 vs. 3.0, p=0.014) and better median pADL scores (17.0 vs. 16.0, p=0.014) than the extracapsular hip fracture patients at four month follow-up, that did not persist at 12 months follow-up.

The difference in physical function in SPPB, BADL and NEADL at four months follow-up between the extracapsular hip fracture patients and intracapsular hip fracture patients, and for SPBB and BADL between the extracapsular fracture and intracapsular fracture (operated with HA) groups, is considered clinically relevant. There could be several reasons for the initial difference in physical function between the groups. Because of the anatomical site of the fracture, an extracapsular fracture will have more bleeding and soft tissue affection than the intracapsular fracture. In our sample the majority of patients suffering from an extracapsular hip fracture were operated with internal fixation (98.6%), and although minimally invasive internal fixation can lead to more pain and less weight bearing postoperatively because there is still a fracture and soft tissue damage that needs healing. Balanced weight bearing of both legs is important for gait function, which in turn will affect the patients' mobility and therefore their rehabilitation. Pfeufer et al. found that patients with extracapsular fractures, operated with internal fixation, had more problems with fully loading their affected leg compared to patients suffering from an intracapsular fracture and operated with hip replacement surgery (39). This might explain the initial faster rehabilitation in the group of patients with an intracapsular fracture that were operated with HA, seeing as they are able to be more mobile earlier postoperatively. This is in line with previous literature, suggesting that patients with an intracapsular fracture have faster initial rehabilitation, but that the functional levels are similar one year postoperatively (201). This might imply different rehabilitation needs in the two patient groups (202, 203).

Studies investigating different hip fracture types, have found that patients with extracapsular fractures have worse outcomes than those with intracapsular fractures in regards to mortality, LOS, discharge destination and pADL (203-205). Most of these studies have not reported whether or not nursing home patients were included, or have excluded them. This complicates the comparison between our study and other studies. Traditionally the differences in outcomes between hip fracture types have been assigned to differences between groups in regards to baseline characteristics, with the extracapsular hip fracture patients being older and frailer, experiencing more blood loss before surgery (38, 206), and being more dependent at the time of fracture (202, 203, 207).

This differs from the findings in our study where we found the hip fracture groups to be similar at baseline and have minimal differences in outcomes during hospital admission and after one year. Some differences in physical function were seen at four months follow-up, however this did not persist after one year. We hypothesized that the small difference in our study could be due to inclusion of nursing home patients. These patients are often frailer, older and are more dependent in ADL at admission, making our sample frailer than many of the populations previously studied. This could explain why the type of fracture could have less impact on outcomes in our sample as the population has less rehabilitation capacity and poorer outcomes in general. This is corroborated by another study including nursing home patients, in which they found similar results, with small short-term differences in function between groups that did not persist over time (201). We therefore performed sensitivity analyses. These showed, in contrary to the aforementioned hypothesis, that when hip fracture patients admitted from a nursing home were excluded, differences between extracapsular and intracapsular hip fracture patients were no longer significant. One might postulate that the home-dwelling population in our study is not directly comparable to home-dwelling populations included in the other studies due to geographical differences in thresholds for nursing home admissions and the offer of home care in the community.

5.4 Methodological considerations

5.4.1 Patient selection

Patients studied in this thesis were initially included in two prospective RCTs, which decreases the risk of selection bias and increases the internal validity of this study. The combined database included a large number of patients, included independently of their cognitive status and there was also inclusion of nursing home patients. This makes the hip fracture population in this study heterogeneous and allows for generalizability, increasing the external validity. However, only the Oslo trial included patients admitted from a nursing home and therefore the number of patients admitted from a nursing home in this study is underrepresented in comparison to the hip fracture population as a whole. In Norway, it is reported that approximately 25% of hip fracture patients live in a nursing home at the time of fracture (200, 208), but in our sample only approximately 14% of the hip fracture patients were admitted from a nursing home. Thus, the proportion of hip fracture patients admitted from a nursing home was not entirely representative for the hip fracture population as a whole in Norway. Furthermore, the nursing home population are often frail and have cognitive impairment, making them less likely to benefit from an intervention and choosing other outcome measures than the ones we studied may be better to measure the effect. Still further, our sample of the hip fracture population might seem healthier than other samples, given the lower proportion of nursing home patients included, which might again affect the external validity.

Since the patients were included from two different hospitals, differences in local practices could have had an impact on the results in this study. However, the studies were planned in concert with similar orthogeriatric models in the intervention, minimizing to an extent the differences in local practices. Furthermore, this was adjusted for in the linear mixed model and the multinomial regression analyses in paper I and II by included site (Oslo vs. Trondheim) as a control variable.

5.4.2 Assessment methods

Both NEADL and BADL were collected using proxy-interview at baseline, where the proxy were asked to fill in the questionnaire based on the 14 previous days before the hip fracture occurred. This could be affected by the knowledge of the recent fracture and thus lead to recall bias. The value the value at both follow-ups were obtained by proxy interview and face-to-face evaluations.

BADL is sensitive to differences in persons with severe or moderate disabilities, but has a floor effect in very frail populations and a ceiling effect in populations with higher function (180). NEADL has good sensitivity to changes in the upper part of the functional range, and has ceiling-effect in populations with higher functional levels (182). The floor effect in both NEADL and BADL in the frailer part of the population, and the ceiling effect in BADL in the more fit part of the population could have diluted the efficacy of the intervention.

The face-to-face evaluations conducted at follow-ups is one of the strengths of this study, and allows for a more objective evaluation of outcome measures.

5.4.3 Statistical considerations

Missing values for the primary endpoints of iADL (NEADL) and pADL (BADL) in this study were imputated manually. Imputation was carried out by imputing the mean score for the remaining items that were answered, if at least 80% of the items on the scale were answered. If this was not the case, the items remained missing. Both linear mixed models and growth mixture models are valid, even with missing values.

Due to the possibility of there being a cluster-effect present, due to the inclusion of patients from two different hospitals, statistical methods were used to account for this. In paper I hospital (Oslo vs. Trondheim) were included as a covariate, while in paper II it was assessed by intra-class correlation coefficient.

In paper III we only conducted bivariate analyses on the outcomes, and the rationale for this were that the groups were similar at baseline. However, this could result in over- or under concluding, as bivariate analysis do not factor in possible confounding factors.

6. Conclusions

Hip fractures are common and serious injuries in older adults, and can have devastating short- and long-term consequences for the patient. Among the outcomes affected are short- and long-term ADL levels. This work has provided information about functional decline after a hip fracture.

6.1 Impact of hip fracture on long-term ADL (and strategies for preserving ADL after a hip fracture)

Comprehensive geriatric care in a geriatric ward is beneficial, and has a positive effect on both iADL and pADL in hip fracture patients one year after surgery. However, the effect is stronger in home-dwelling patients, suggesting different rehabilitation potential and needs in different sub-groups of the hip fracture population.

In our material, trajectory analysis showed that no group of hip fracture patients regained their pre-fracture iADL or pADL levels. Functional decline is steepest in the first four months following hip fracture surgery, which was particularly steep in one group for both iADL and pADL with relatively good pre-fracture ADL levels. Higher age, higher ASA score and more cognitive impairment were associated with belonging to the groups with worse trajectories in ADL. These groups are clinically interesting and relevant, and might show a potential for rehabilitation. Identifying patients belonging to different groups can be useful for resource and discharge planning, and when informing patients and next of kin of prognosis.

6.2 Short- and long-term outcomes in extracapsular vs. intracapsular fractures

Patients with an extracapsular fracture and patients with an intracapsular fracture were found to be similar at baseline and have little differences between them at follow-up. There was a difference in SPPB and ADL at four months follow-up, which did not persist 12 months after hip fracture when comparing the extracapsular hip fracture patients to the intracapsular hip fracture patients. This might imply that the intracapsular fracture patients have a faster initial rehabilitation, but that both groups have the same functional rehabilitation capacity and will end up at the same functional level one year after surgery. Moreover, there seems to be a difference in rehabilitation needs early after surgery in these groups, with the extracapsular fracture group needing more time and/or intensified rehabilitation.

The difference in surgical procedure between the hip fracture types, as well as the differences in the hip fractures themselves, might explain the difference in rehabilitation needs between these groups. Patients suffering from an extracapsular fracture might experience more pain, less weight bearing and have longer healing periods postoperatively, which might impede mobilization and rehabilitation.

7. Suggestion for future research

Evidence suggests that orthogeriatric care is beneficial for hip fracture patients. Which orthogeriatric model is most effective still remains unclear. Future studies should aim at investigating which orthogeriatric model is most beneficial for hip fracture patients. Specifically, there is a need for more studies comparing the different models, perhaps by RCTs, to find if there is an orthogeriatric model that is superior in the care of hip fracture patients. Furthermore, which sub-groups of hip fracture patients that benefit the most from an orthogeriatric care model remains largely unexplored in the literature, and should be devoted more focus. Investigating this can be valuable for prioritizing resources and individualizing treatment.

There is a need for more research on ADL after hip fracture surgery; more specifically, it should be studied more in relation to the effect of orthogeriatrics. When it is studied, it should include longer follow-up periods (for up to one year, or possibly longer) to ascertain the true effects of a hip fracture, and the potential benefits from an intervention.

Loss in iADL and pADL functions have a major impact on hip fracture patients' life, and most patients do not regain their pre-fracture levels. Future research should target identifying different groups of hip fracture patients with different rehabilitation needs, and subsequently finding what the rehabilitation need is within each group. There seems to be a group of hip fracture patients with relatively good pre-fracture function, who are at high risk of large functional decline after a hip fracture, and who should be dedicated more investigation. Finding what characterizes them of being at risk and how to treat and rehabilitate them optimally can lead to decreasing the functional decline after hip fracture.

Patients with an intracapsular fracture operated with HA have faster initial recovery in regards to mobility and ADL compared to extracapsular hip fracture patients. Future studies should focus on how to optimize the postoperative conditions for the extracapsular hip fracture patients, aiding them in more weight bearing and perhaps better pain management to facilitate this. Furthermore, there is a need for more studies investigating the difference between the groups in a systematic manner, including nursing home patients.

Including hip fracture patients that live in a nursing home at the time of fracture is important for generalizability of studies, seeing as they make up a significant proportion of the hip fracture population. Studying these hip fracture patients might require other measurements than LOS, mortality, ADL and mobility.

References

1. Kanis JA, Odén A, McCloskey EV, Johansson H, Wahl DA, Cooper C. A systematic review of hip fracture incidence and probability of fracture worldwide. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2012;23(9):2239-56.
2. Kannegaard PN, van der Mark S, Eiken P, Abrahamsen B. Excess mortality in men compared with women following a hip fracture. National analysis of comedications, comorbidity and survival. Age and ageing. 2010;39(2):203-9.
3. Støen RO, Nordsletten L, Meyer HE, Frihagen JF, Falch JA, Lofthus CM. Hip fracture incidence is decreasing in the high incidence area of Oslo, Norway. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2012;23(10):2527-34.
4. The burden of musculoskeletal conditions at the start of the new millennium. World Health Organ Tech Rep Ser. 2003;919:i-x, 1-218, back cover.
5. Watne LO, Torbergsen AC, Conroy S, Engedal K, Frihagen F, Hjorthaug GA, et al. The effect of a pre- and postoperative orthogeriatric service on cognitive function in patients with hip fracture: randomized controlled trial (Oslo Orthogeriatric Trial). BMC medicine. 2014;12:63.
6. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. Injury. 2018;49(8):1458-60.
7. Cummings SR, Melton LJ. Epidemiology and outcomes of osteoporotic fractures. Lancet (London, England). 2002;359(9319):1761-7.
8. Cheng SY, Levy AR, Lefaivre KA, Guy P, Kuramoto L, Sobolev B. Geographic trends in incidence of hip fractures: a comprehensive literature review. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2011;22(10):2575-86.
9. Sterling RS. Gender and race/ethnicity differences in hip fracture incidence, morbidity, mortality, and function. Clinical orthopaedics and related research. 2011;469(7):1913-8.
10. Gjertsen JE, Dybvik E, Furnes O, Fevang JM, Havelin LI, Matre K, et al. Improved outcome after hip fracture surgery in Norway. Acta orthopaedica. 2017;88(5):505-11.
11. Xue QL. The frailty syndrome: definition and natural history. Clin Geriatr Med. 2011;27(1):1-15.
12. Ensrud KE, Ewing SK, Taylor BC, Fink HA, Stone KL, Cauley JA, et al. Frailty and risk of falls, fracture, and mortality in older women: the study of osteoporotic fractures. The journals of gerontology Series A, Biological sciences and medical sciences. 2007;62(7):744-51.
13. Cawthon PM, Marshall LM, Michael Y, Dam TT, Ensrud KE, Barrett-Connor E, et al. Frailty in older men: prevalence, progression, and relationship with mortality. Journal of the American Geriatrics Society. 2007;55(8):1216-23.
14. Gill TM, Murphy TE, Gahbauer EA, Allore HG. Association of injurious falls with disability outcomes and nursing home admissions in community-living older persons. Am J Epidemiol. 2013;178(3):418-25.
15. Härlein J, Dassen T, Halfens RJ, Heinze C. Fall risk factors in older people with dementia or cognitive impairment: a systematic review. J Adv Nurs. 2009;65(5):922-33.
16. Muir SW, Gopaul K, Montero Odasso MM. The role of cognitive impairment in fall risk among older adults: a systematic review and meta-analysis. Age and ageing. 2012;41(3):299-308.

17. Lewis SR, Macey R, Stokes J, Cook JA, Eardley WG, Griffin XL. Surgical interventions for treating intracapsular hip fractures in older adults: a network meta-analysis. The Cochrane database of systematic reviews. 2022;2(2):Cd013404.
18. Lewis SR, Macey R, Lewis J, Stokes J, Gill JR, Cook JA, et al. Surgical interventions for treating extracapsular hip fractures in older adults: a network meta-analysis. The Cochrane database of systematic reviews. 2022;2(2):Cd013405.
19. Kyriacou H, Khan WS. Important perioperative factors, guidelines and outcomes in the management of hip fracture. J Perioper Pract. 2021;31(4):140-6.
20. Dolatowski FC, Frihagen F, Bartels S, Opland V, Šaltytė Benth J, Talsnes O, et al. Screw Fixation Versus Hemiarthroplasty for Nondisplaced Femoral Neck Fractures in Elderly Patients: A Multicenter Randomized Controlled Trial. J Bone Joint Surg Am. 2019;101(2):136-44.
21. Fracture fixation in the operative management of hip fractures (FAITH): an international, multicentre, randomised controlled trial. Lancet (London, England). 2017;389(10078):1519-27.
22. Bhandari M, Einhorn TA, Guyatt G, Schemitsch EH, Zura RD, Sprague S, et al. Total Hip Arthroplasty or Hemiarthroplasty for Hip Fracture. The New England journal of medicine. 2019;381(23):2199-208.
23. Fischer H, Maleitzke T, Eder C, Ahmad S, Stöckle U, Braun KF. Management of proximal femur fractures in the elderly: current concepts and treatment options. Eur J Med Res. 2021;26(1):86.
24. Garrison I, Domingue G, Honeycutt MW. Subtrochanteric femur fractures: current review of management. EFORT Open Rev. 2021;6(2):145-51.
25. Grønhaug KML, Dybvik E, Matre K, Östman B, Gjertsen JE. Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures : 17,341 patients from the Norwegian Hip Fracture Register. Bone Joint J. 2022;104-b(2):274-82.
26. Lewis SR, Macey R, Gill JR, Parker MJ, Griffin XL. Cephalomedullary nails versus extramedullary implants for extracapsular hip fractures in older adults. The Cochrane database of systematic reviews. 2022;1(1):Cd000093.
27. Mattisson L, Bojan A, Enocson A. Epidemiology, treatment and mortality of trochanteric and subtrochanteric hip fractures: data from the Swedish fracture register. BMC musculoskeletal disorders. 2018;19(1):369.
28. Parker M, Raval P, Gjertsen JE. Nail or plate fixation for A3 trochanteric hip fractures: A systematic review of randomised controlled trials. Injury. 2018;49(7):1319-23.
29. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, et al. Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet (London, England). 2015;385(9978):1623-33.
30. Abrahamsen B, van Staa T, Ariely R, Olson M, Cooper C. Excess mortality following hip fracture: a systematic epidemiological review. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2009;20(10):1633-50.
31. Haentjens P, Magaziner J, Colón-Emeric CS, Vanderschueren D, Milisen K, Velkeniers B, et al. Meta-analysis: excess mortality after hip fracture among older women and men. Ann Intern Med. 2010;152(6):380-90.
32. de Luise C, Brimacombe M, Pedersen L, Sørensen HT. Comorbidity and mortality following hip fracture: a population-based cohort study. Aging clinical and experimental research. 2008;20(5):412-8.

33. Ma RS, Gu GS, Huang X, Zhu D, Zhang Y, Li M, et al. Postoperative mortality and morbidity in octogenarians and nonagenarians with hip fracture: an analysis of perioperative risk factors. Chin J Traumatol. 2011;14(6):323-8.
34. Smith TO, Cooper A, Peryer G, Griffiths R, Fox C, Cross J. Factors predicting incidence of post-operative delirium in older people following hip fracture surgery: a systematic review and meta-analysis. International journal of geriatric psychiatry. 2017;32(4):386-96.
35. González-Zabaleta J, Pita-Fernandez S, Seoane-Pillado T, López-Calviño B, Gonzalez-Zabaleta JL. Comorbidity as a predictor of mortality and mobility after hip fracture. Geriatrics & gerontology international. 2016;16(5):561-9.
36. Krogseth M, Watne LO, Juliebo V, Skovlund E, Engedal K, Frihagen F, et al. Delirium is a risk factor for further cognitive decline in cognitively impaired hip fracture patients. Archives of gerontology and geriatrics. 2016;64:38-44.
37. Krogseth M, Wyller TB, Engedal K, Juliebø V. Delirium is an important predictor of incident dementia among elderly hip fracture patients. Dementia and geriatric cognitive disorders. 2011;31(1):63-70.
38. Harper KD, Navo P, Ramsey F, Jallow S, Rehman S. "Hidden" Preoperative Blood Loss With Extracapsular Versus Intracapsular Hip Fractures: What Is the Difference? Geriatric orthopaedic surgery & rehabilitation. 2017;8(4):202-7.
39. Pfeufer D, Grabmann C, Mehaffey S, Keppler A, Böcker W, Kammerlander C, et al. Weight bearing in patients with femoral neck fractures compared to pertrochanteric fractures: A postoperative gait analysis. Injury. 2019;50(7):1324-8.
40. Dyer SM, Crotty M, Fairhall N, Magaziner J, Beaupre LA, Cameron ID, et al. A critical review of the long-term disability outcomes following hip fracture. BMC geriatrics. 2016;16(1):158.
41. Osnes EK, Lofthus CM, Meyer HE, Falch JA, Nordsletten L, Cappelen I, et al. Consequences of hip fracture on activities of daily life and residential needs. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2004;15(7):567-74.
42. Magaziner J, Hawkes W, Hebel JR, Zimmerman SI, Fox KM, Dolan M, et al. Recovery from hip fracture in eight areas of function. The journals of gerontology Series A, Biological sciences and medical sciences. 2000;55(9):M498-507.
43. Jaatinen R, Luukkaala T, Hongisto MT, Kujala MA, Nuotio MS. Factors associated with and 1-year outcomes of fear of falling in a geriatric post-hip fracture assessment. Aging clinical and experimental research. 2022;34(9):2107-16.
44. Su SF, Lin SN. Effects of comprehensive geriatric care on depressive symptoms, emergency department visits, re-hospitalization and discharge to the same residence in older persons receiving hip-fracture surgery: A meta-analysis. Int J Nurs Pract. 2022;28(6):e13099.
45. Heidari ME, Naghibi Irvani SS, Dalvand P, Khadem M, Eskandari F, Torabi F, et al. Prevalence of depression in older people with hip fracture: A systematic review and meta-analysis. International journal of orthopaedic and trauma nursing. 2021;40:100813.
46. Shyu YI, Chen MC, Cheng HS, Deng HC, Liang J, Wu CC, et al. Severity of depression risk predicts health outcomes and recovery following surgery for hip-fractured elders. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2008;19(11):1541-7.
47. Marsh DR. The Orthogeriatric Approach: Progress Worldwide. In: Falaschi P, Marsh DR, editors. Orthogeriatrics. Cham: Springer International Publishing; 2017. p. 1-18.
48. Devas MB. Geriatric orthopaedics. Br Med J. 1974;1(5900):190-2.

49. Hempsall VJ, Robertson DR, Campbell MJ, Briggs RS. Orthopaedic geriatric care--is it effective? A prospective population-based comparison of outcome in fractured neck of femur. J R Coll Physicians Lond. 1990;24(1):47-50.
50. Van Heghe A, Mordant G, Dupont J, Dejaeger M, Laurent MR, Gielen E. Effects of Orthogeriatric Care Models on Outcomes of Hip Fracture Patients: A Systematic Review and Meta-Analysis. Calcified tissue international. 2022;110(2):162-84.
51. Kammerlander C, Roth T, Friedman SM, Suhm N, Luger TJ, Kammerlander-Knauer U, et al. Ortho-geriatric service--a literature review comparing different models. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2010;21(Suppl 4):S637-46.
52. Grigoryan KV, Javedan H, Rudolph JL. Orthogeriatric care models and outcomes in hip fracture patients: a systematic review and meta-analysis. Journal of orthopaedic trauma. 2014;28(3):e49-55.
53. Giusti A, Barone A, Razzano M, Pizzonia M, Pioli G. Optimal setting and care organization in the management of older adults with hip fracture. European journal of physical and rehabilitation medicine. 2011;47(2):281-96.
54. Boyd RV, Hawthorne J, Wallace WA, Worlock PH, Compton EH. The Nottingham orthogeriatric unit after 1000 admissions. Injury. 1983;15(3):193-6.
55. Lundstrom M, Edlund A, Lundstrom G, Gustafson Y. Reorganization of nursing and medical care to reduce the incidence of postoperative delirium and improve rehabilitation outcome in elderly patients treated for femoral neck fractures. Scandinavian journal of caring sciences. 1999;13(3):193-200.
56. Kennie DC, Reid J, Richardson IR, Kiamari AA, Kelt C. Effectiveness of geriatric rehabilitative care after fractures of the proximal femur in elderly women: a randomised clinical trial. BMJ (Clinical research ed). 1988;297(6656):1083-6.
57. Swanson CE, Day GA, Yelland CE, Broome JR, Massey L, Richardson HR, et al. The management of elderly patients with femoral fractures. A randomised controlled trial of early intervention versus standard care. The Medical journal of Australia. 1998;169(10):515-8.
58. Gilchrist WJ, Newman RJ, Hamblen DL, Williams BO. Prospective randomised study of an orthopaedic geriatric inpatient service. BMJ (Clinical research ed). 1988;297(6656):1116-8.
59. Gustafson Y, Brannstrom B, Berggren D, Ragnarsson JI, Sigaard J, Bucht G, et al. A geriatric-anesthesiologic program to reduce acute confusional states in elderly patients treated for femoral neck fractures. Journal of the American Geriatrics Society. 1991;39(7):655-62.
60. Zuckerman JD, Sakales SR, Fabian DR, Frankel VH. Hip fractures in geriatric patients. Results of an interdisciplinary hospital care program. Clinical orthopaedics and related research. 1992(274):213-25.
61. Antonelli Incalzi R, Gemma A, Capparella O, Bernabei R, Sanguinetti C, Carbonin PU. Continuous geriatric care in orthopedic wards: a valuable alternative to orthogeriatric units. Aging (Milan, Italy). 1993;5(3):207-16.
62. Milisen K, Foreman MD, Abraham IL, De Geest S, Godderis J, Vandermeulen E, et al. A nurse-led interdisciplinary intervention program for delirium in elderly hip-fracture patients. Journal of the American Geriatrics Society. 2001;49(5):523-32.
63. Naglie G, Tansey C, Kirkland JL, Ogilvie-Harris DJ, Detsky AS, Etchells E, et al. Interdisciplinary inpatient care for elderly people with hip fracture: a randomized controlled trial. CMAJ : Canadian Medical Association journal = journal de l'Association medicale canadienne. 2002;167(1):25-32.

64. Shyu YI, Liang J, Wu CC, Su JY, Cheng HS, Chou SW, et al. A pilot investigation of the short-term effects of an interdisciplinary intervention program on elderly patients with hip fracture in Taiwan. Journal of the American Geriatrics Society. 2005;53(5):811-8.
65. Ho WW, Kwan Dai DL, Liu KW, Chow KM, Lau E, Woo J, et al. To investigate the effect and cost-effectiveness of implementing an orthogeriatric intervention for elderly patients with acute hip fracture: the experience in Hong Kong. Journal of the American Geriatrics Society. 2009;57(11):2153-4.
66. Marcantonio ER, Flacker JM, Wright RJ, Resnick NM. Reducing delirium after hip fracture: a randomized trial. Journal of the American Geriatrics Society. 2001;49(5):516-22.
67. Adunsky A, Lusky A, Arad M, Heruti RJ. A comparative study of rehabilitation outcomes of elderly hip fracture patients: the advantage of a comprehensive orthogeriatric approach. The journals of gerontology Series A, Biological sciences and medical sciences. 2003;58(6):542-7.
68. Vidan M, Serra JA, Moreno C, Riquelme G, Ortiz J. Efficacy of a comprehensive geriatric intervention in older patients hospitalized for hip fracture: a randomized, controlled trial. Journal of the American Geriatrics Society. 2005;53(9):1476-82.
69. Stenvall M, Olofsson B, Lundstrom M, Englund U, Borssen B, Svensson O, et al. A multidisciplinary, multifactorial intervention program reduces postoperative falls and injuries after femoral neck fracture. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2007;18(2):167-75.
70. Mazzola P, De Filippi F, Castoldi G, Galetti P, Zatti G, Annoni G. A comparison between two co-managed geriatric programmes for hip fractured elderly patients. Aging clinical and experimental research. 2011;23(5-6):431-6.
71. Gonzalez-Montalvo JI, Alarcon T, Mauleon JL, Gil-Garay E, Gotor P, Martin-Vega A. The orthogeriatric unit for acute patients: a new model of care that improves efficiency in the management of patients with hip fracture. Hip international : the journal of clinical and experimental research on hip pathology and therapy. 2010;20(2):229-35.
72. Koval KJ, Chen AL, Aharonoff GB, Egol KA, Zuckerman JD. Clinical pathway for hip fractures in the elderly: the Hospital for Joint Diseases experience. Clinical orthopaedics and related research. 2004(425):72-81.
73. Barone A, Giusti A, Pizzonia M, Razzano M, Palummeri E, Pioli G. A comprehensive geriatric intervention reduces short- and long-term mortality in older people with hip fracture. Journal of the American Geriatrics Society. 2006;54(7):1145-7.
74. Khan R, Fernandez C, Kashifl F, Shedden R, Diggory P. Combined orthogeriatric care in the management of hip fractures: a prospective study. Annals of the Royal College of Surgeons of England. 2002;84(2):122-4.
75. Adunsky A, Arad M, Levi R, Blankstein A, Zeilig G, Mizrachi E. Five-year experience with the 'Sheba' model of comprehensive orthogeriatric care for elderly hip fracture patients. Disability and rehabilitation. 2005;27(18-19):1123-7.
76. Adunsky A, Lerner-Geva L, Blumstein T, Boyko V, Mizrahi E, Arad M. Improved survival of hip fracture patients treated within a comprehensive geriatric hip fracture unit, compared with standard of care treatment. Journal of the American Medical Directors Association. 2011;12(6):439-44.
77. Ginsberg G, Adunsky A, Rasooly I. A cost-utility analysis of a comprehensive orthogeriatric care for hip fracture patients, compared with standard of care treatment. Hip international : the journal of clinical and experimental research on hip pathology and therapy. 2013;23(6):570-5.

78. Roberts HC, Pickering RM, Onslow E, Clancy M, Powell J, Roberts A, et al. The effectiveness of implementing a care pathway for femoral neck fracture in older people: a prospective controlled before and after study. Age and ageing. 2004;33(2):178-84.
79. Khasraghi FA, Christmas C, Lee EJ, Mears SC, Wenz JF, Sr. Effectiveness of a multidisciplinary team approach to hip fracture management. Journal of surgical orthopaedic advances. 2005;14(1):27-31.
80. Shyu YI, Liang J, Wu CC, Su JY, Cheng HS, Chou SW, et al. Interdisciplinary intervention for hip fracture in older Taiwanese: benefits last for 1 year. The journals of gerontology Series A, Biological sciences and medical sciences. 2008;63(1):92-7.
81. Shyu YI, Liang J, Wu CC, Su JY, Cheng HS, Chou SW, et al. Two-year effects of interdisciplinary intervention for hip fracture in older Taiwanese. Journal of the American Geriatrics Society. 2010;58(6):1081-9.
82. Shyu YI, Tsai WC, Chen MC, Liang J, Cheng HS, Wu CC, et al. Two-year effects of an interdisciplinary intervention on recovery following hip fracture in older Taiwanese with cognitive impairment. International journal of geriatric psychiatry. 2012;27(5):529-38.
83. Liu HY, Tseng MY, Li HJ, Wu CC, Cheng HS, Yang CT, et al. Comprehensive care improves physical recovery of hip-fractured elderly Taiwanese patients with poor nutritional status. Journal of the American Medical Directors Association. 2014;15(6):416-22.
84. Wong Tin Niam DM, Bruce JJ, Bruce DG. Quality project to prevent delirium after hip fracture. Australasian Journal on Ageing. 2005;24(3):174-7.
85. Fisher AA, Davis MW, Rubenach SE, Sivakumaran S, Smith PN, Budge MM. Outcomes for older patients with hip fractures: the impact of orthopedic and geriatric medicine cocare. Journal of orthopaedic trauma. 2006;20(3):172-8; discussion 9-80.
86. Stenvall M, Olofsson B, Nyberg L, Lundstrom M, Gustafson Y. Improved performance in activities of daily living and mobility after a multidisciplinary postoperative rehabilitation in older people with femoral neck fracture: a randomized controlled trial with 1-year follow-up. Journal of rehabilitation medicine. 2007;39(3):232-8.
87. Stenvall M, Berggren M, Lundstrom M, Gustafson Y, Olofsson B. A multidisciplinary intervention program improved the outcome after hip fracture for people with dementia--subgroup analyses of a randomized controlled trial. Archives of gerontology and geriatrics. 2012;54(3):e284-9.
88. Lundstrom M, Olofsson B, Stenvall M, Karlsson S, Nyberg L, Englund U, et al. Postoperative delirium in old patients with femoral neck fracture: a randomized intervention study. Aging clinical and experimental research. 2007;19(3):178-86.
89. Friedman SM, Mendelson DA, Kates SL, McCann RM. Geriatric co-management of proximal femur fractures: total quality management and protocol-driven care result in better outcomes for a frail patient population. Journal of the American Geriatrics Society. 2008;56(7):1349-56.
90. Friedman SM, Mendelson DA, Bingham KW, Kates SL. Impact of a comanaged Geriatric Fracture Center on short-term hip fracture outcomes. Archives of internal medicine. 2009;169(18):1712-7.
91. Kates SL, Blake D, Bingham KW, Kates OS, Mendelson DA, Friedman SM. Comparison of an organized geriatric fracture program to United States government data. Geriatric orthopaedic surgery & rehabilitation. 2010;1(1):15-21.
92. Kates SL, Mendelson DA, Friedman SM. Co-managed care for fragility hip fractures (Rochester model). Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2010;21(Suppl 4):S621-5.
93. Kates SL, Mendelson DA, Friedman SM. The value of an organized fracture program for the elderly: early results. Journal of orthopaedic trauma. 2011;25(4):233-7.

94. Leung AH, Lam TP, Cheung WH, Chan T, Sze PC, Lau T, et al. An orthogeriatric collaborative intervention program for fragility fractures: a retrospective cohort study. The Journal of trauma. 2011;71(5):1390-4.
95. Miura LN, DiPiero AR, Homer LD. Effects of a geriatrician-led hip fracture program: improvements in clinical and economic outcomes. Journal of the American Geriatrics Society. 2009;57(1):159-67.
96. Cogan L, Martin AJ, Kelly LA, Duggan J, Hynes D, Power D. An audit of hip fracture services in the Mater Hospital Dublin 2001 compared with 2006. Irish journal of medical science. 2010;179(1):51-5.
97. Deschodt M, Braes T, Broos P, Sermon A, Boonen S, Flamaing J, et al. Effect of an inpatient geriatric consultation team on functional outcome, mortality, institutionalization, and readmission rate in older adults with hip fracture: a controlled trial. Journal of the American Geriatrics Society. 2011;59(7):1299-308.
98. Burgers PT, Van Lieshout EM, Verhelst J, Dawson I, de Rijcke PA. Implementing a clinical pathway for hip fractures; effects on hospital length of stay and complication rates in five hundred and twenty six patients. International orthopaedics. 2014;38(5):1045-50.
99. Chen CH, Huang PJ, Huang HT, Lin SY, Wang HY, Fang TJ, et al. Impact of orthogeriatric care, comorbidity, and complication on 1-year mortality in surgical hip fracture patients: An observational study. Medicine. 2019;98(47):e17912.
100. O'Mara-Gardner K, Redfern RE, Bair JM. Establishing a Geriatric Hip Fracture Program at a Level 1 Community Trauma Center. Orthop Nurs. 2020;39(3):171-9.
101. van der Zwaard BC, Stein CE, Bootsma JEM, van Geffen H, Douw CM, Keijsers C. Fewer patients undergo surgery when adding a comprehensive geriatric assessment in older patients with a hip fracture. Archives of orthopaedic and trauma surgery. 2020;140(4):487-92.
102. Werner M, Krause O, Macke C, Herold L, Ranker A, Krettek C, et al. Orthogeriatric co-management for proximal femoral fractures. Can two additions make a big difference? BMC musculoskeletal disorders. 2020;21(1):371.
103. Lee JC, Koo K, Wong EKC, Naqvi R, Wong CL. Impact of an orthogeriatric collaborative care model for older adults with hip fracture in a community hospital setting. Can J Surg. 2021;64(2):E211-e7.
104. Dy CJ, Dossous PM, Ton QV, Hollenberg JP, Lorich DG, Lane JM. The medical orthopaedic trauma service: an innovative multidisciplinary team model that decreases in-hospital complications in patients with hip fractures. Journal of orthopaedic trauma. 2012;26(6):379-83.
105. Gupta A. The effectiveness of geriatrician-led comprehensive hip fracture collaborative care in a new acute hip unit based in a general hospital setting in the UK. The journal of the Royal College of Physicians of Edinburgh. 2014;44(1):20-6.
106. Suhm N, Kaelin R, Studer P, Wang Q, Kressig RW, Rikli D, et al. Orthogeriatric care pathway: a prospective survey of impact on length of stay, mortality and institutionalisation. Archives of orthopaedic and trauma surgery. 2014;134(9):1261-9.
107. Forni S, Pieralli F, Sergi A, Lorini C, Bonaccorsi G, Vannucci A. Mortality after hip fracture in the elderly: The role of a multidisciplinary approach and time to surgery in a retrospective observational study on 23,973 patients. Archives of gerontology and geriatrics. 2016;66:13-7.
108. Gosch M, Hoffmann-Weltin Y, Roth T, Blauth M, Nicholas JA, Kammerlander C. Orthogeriatric co-management improves the outcome of long-term care residents with fragility fractures. Archives of orthopaedic and trauma surgery. 2016;136(10):1403-9.
109. Kristensen PK, Thillemann TM, Soballe K, Johnsen SP. Can improved quality of care explain the success of orthogeriatric units? A population-based cohort study. Age and ageing. 2016;45(1):66-71.

110. Middleton M, Wan B, da Assuncao R. Improving hip fracture outcomes with integrated orthogeriatric care: a comparison between two accepted orthogeriatric models. Age and ageing. 2016.
111. Stenqvist C, Madsen CM, Riis T, Jorgensen HL, Duus BR, Lauritzen JB, et al. Orthogeriatric Service Reduces Mortality in Patients With Hip Fracture. Geriatric orthopaedic surgery & rehabilitation. 2016;7(2):67-73.
112. Folbert EC, Hegeman JH, Vermeer M, Regtuijt EM, van der Velde D, Ten Duis HJ, et al. Improved 1-year mortality in elderly patients with a hip fracture following integrated orthogeriatric treatment. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2017;28(1):269-77.
113. Henderson CY, Shanahan E, Butler A, Lenehan B, O'Connor M, Lyons D, et al. Dedicated orthogeriatric service reduces hip fracture mortality. Irish journal of medical science. 2017;186(1):179-84.
114. Jackson K, Bachhuber M, Bowden D, Etter K, Tong C. Comprehensive Hip Fracture Care Program: Successive Implementation in 3 Hospitals. Geriatric orthopaedic surgery & rehabilitation. 2019;10:2151459319846057.
115. Aletto C, Aicale R, Pezzuti G, Bruno F, Maffulli N. Impact of an orthogeriatrician on length of stay of elderly patient with hip fracture. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2020;31(11):2161-6.
116. Lieten S, Pien K, Van Laere S, Bravenboer B, Scheerlinck T. Introduction of the orthogeriatric co-management model increases the quality of care : a pilot study. Acta Orthop Belg. 2020;86(4):580-7.
117. Pablos-Hernández C, González-Ramírez A, da Casa C, Luis MM, García-Iglesias MA, Julián-Enriquez JM, et al. Time to Surgery Reduction in Hip Fracture Patients on an Integrated Orthogeriatric Unit: A Comparative Study of Three Healthcare Models. Orthopaedic surgery. 2020;12(2):457-62.
118. Rapp K, Becker C, Todd C, Rothenbacher D, Schulz C, König HH, et al. The Association Between Orthogeriatric Co-Management and Mortality Following Hip Fracture. Deutsches Arzteblatt international. 2020;117(4):53-9.
119. Schuijt HJ, Kusen J, van Hernen JJ, van der Vet P, Geraghty O, Smeeing DPJ, et al. Orthogeriatric Trauma Unit Improves Patient Outcomes in Geriatric Hip Fracture Patients. Geriatric orthopaedic surgery & rehabilitation. 2020;11:2151459320949476.
120. Tittel S, Burkhardt J, Roll C, Kinner B. Clinical pathways for geriatric patients with proximal femoral fracture improve process and outcome. Orthopaedics & traumatology, surgery & research : OTSR. 2020;106(1):141-7.
121. Pollmann CT, Mellingsæter MR, Neerland BE, Straume-Næsheim T, Årøen A, Watne LO. Orthogeriatric co-management reduces incidence of delirium in hip fracture patients. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2021;32(11):2225-33.
122. Quaranta M, Miranda L, Oliva F, Migliorini F, Pezzuti G, Maffulli N. Haemoglobin and transfusions in elderly patients with hip fractures: the effect of a dedicated orthogeriatrician. Journal of orthopaedic surgery and research. 2021;16(1):387.
123. Schulz C, Büchele G, Peter RS, Rothenbacher D, Brettschneider C, Liener UC, et al. Health-economic evaluation of collaborative orthogeriatric care for patients with a hip fracture in Germany: a retrospective cohort study using health and long-term care insurance claims data. Eur J Health Econ. 2021;22(6):873-85.

124. van Leendert JAA, Linkens A, Poeze M, Pijpers E, Magdelijns F, Ten Broeke RHM, et al. Mortality in hip fracture patients after implementation of a nurse practitioner-led orthogeriatric care program: results of a 1-year follow-up. Age and ageing. 2021;50(5):1744-50.
125. Balvis-Balvis PM, Dominguez-Prado DM, Ferradás-García L, Pérez-García M, Garcia-Reza A, Castro-Menendez M. Influence of integrated orthogeriatric care on morbidity and mortality and length of hospital stay for hip fracture. Rev Esp Cir Ortop Traumatol. 2022;66(1):29-37.
126. Casanova Querol T, Santiago Bautista JM, Lafuente Salinas M, Güell Farré E, Girós Torres J, Martín-Baranera M, et al. Health outcomes after the implementation of multidisciplinary clinical guidelines for the care of hip fractures. Rev Clin Esp (Barc). 2022;222(2):73-81.
127. Fluck B, Yeong K, Lisk R, Watters H, Robin J, Fluck D, et al. Changes in Characteristics and Outcomes of Patients Undergoing Surgery for Hip Fractures Following the Initiation of Orthogeriatric Service: Temporal Trend Analysis. Calcified tissue international. 2022;110(2):185-95.
128. Heyzer L, Ramason R, De Castro Molina JA, Lim Chan WW, Loong CY, Kee Kwek EB. Integrated hip fracture care pathway (IHFCP): reducing complications and improving outcomes. Singapore medical journal. 2022;63(8):439-44.
129. Higashikawa T, Shigemoto K, Moriyama M, Usuda D, Hangyou M, Inujima H, et al. Orthogeriatric co-management at a regional core hospital as a new multidisciplinary approach in Japanese hip fracture operation. Journal of orthopaedic science : official journal of the Japanese Orthopaedic Association. 2022.
130. Liu G, Yang MH, Zhu SW, Zhang P, Wang G, Wang MY, et al. Effect of Orthogeriatric Co-Management on Geriatric Hip Fractures in China. Orthopaedic surgery. 2022;14(4):671-7.
131. Yee DKH, Lau TW, Fang C, Ching K, Cheung J, Leung F. Orthogeriatric Multidisciplinary Co-Management Across Acute and Rehabilitation Care Improves Length of Stay, Functional Outcomes and Complications in Geriatric Hip Fracture Patients. Geriatric orthopaedic surgery & rehabilitation. 2022;13:21514593221085813.
132. Bugaevsky Y, Levy Y, Hershkovitz A, Ocheretny I, Nissenholtz A, Cooper L, et al. Characteristics and Outcomes of Hip Fracture Patients Hospitalized in an Orthogeriatric Unit Versus an Orthopedic Department: A Retrospective Cohort Study. Geriatric orthopaedic surgery & rehabilitation. 2021;12:2151459320986299.
133. Rostagno C, Buzzi R, Campanacci D, Boccacini A, Cartei A, Virgili G, et al. In Hospital and 3-Month Mortality and Functional Recovery Rate in Patients Treated for Hip Fracture by a Multidisciplinary Team. PloS one. 2016;11(7):e0158607.
134. Flikweert ER, Izaks GJ, Reininga IH, Wendt KW, Stevens M. Evaluation of the effect of a comprehensive multidisciplinary care pathway for hip fractures: design of a controlled study. BMC musculoskeletal disorders. 2013;14:291.
135. Flikweert ER, Wendt KW, Diercks RL, Izaks GJ, Stewart R, Stevens M, et al. A comprehensive multidisciplinary care pathway for hip fractures better outcome than usual care? Injury. 2021;52(7):1819-25.
136. Wagner P, Fuentes P, Diaz A, Martinez F, Amenabar P, Schweitzer D, et al. Comparison of complications and length of hospital stay between orthopedic and orthogeriatric treatment in elderly patients with a hip fracture. Geriatric orthopaedic surgery & rehabilitation. 2012;3(2):55-8.
137. Ogawa T, Schermann H, Khadka A, Moross J, Moriwaki M, Fushimi K, et al. Impact of orthogeriatric care management by orthopedic surgeons and physicians on in-hospital

clinical outcomes: A difference-in-difference analysis. Geriatrics & gerontology international. 2022;22(2):138-44.
138. Zhu T, Yu J, Ma Y, Qin Y, Li N, Yang H. Effectiveness of Perioperative Comprehensive Evaluation of Hip Fracture in the Elderly. Comput Intell Neurosci. 2022;2022:4124354.
139. Saber HG, Aly M. The effectiveness of an orthogeriatric service in Ain Shams University, Egypt: a quality improvement study. Archives of osteoporosis. 2022;17(1):101.
140. Deschodt M, Braes T, Flamaing J, Detroyer E, Broos P, Haentjens P, et al. Preventing delirium in older adults with recent hip fracture through multidisciplinary geriatric consultation. Journal of the American Geriatrics Society. 2012;60(4):733-9.
141. Deschodt M, Flamaing J, Rock G, Boland B, Boonen S, Milisen K. Implementation of inpatient geriatric consultation teams and geriatric resource nurses in acute hospitals: a national survey study. International journal of nursing studies. 2012;49(7):842-9.
142. Gregersen M, Morch MM, Hougaard K, Damsgaard EM. Geriatric intervention in elderly patients with hip fracture in an orthopedic ward. Journal of injury & violence research. 2012;4(2):45-51.
143. Bhattacharyya R, Agrawal Y, Elphick H, Blundell C. A unique orthogeriatric model: a step forward in improving the quality of care for hip fracture patients. International journal of surgery (London, England). 2013;11(10):1083-6.
144. Flikweert ER, Izaks GJ, Knobben BA, Stevens M, Wendt K. The development of a comprehensive multidisciplinary care pathway for patients with a hip fracture: design and results of a clinical trial. BMC musculoskeletal disorders. 2014;15:188.
145. Prestmo A, Saltvedt I, Helbostad JL, Taraldsen K, Thingstad P, Lydersen S, et al. Who benefits from orthogeriatric treatment? Results from the Trondheim hip-fracture trial. BMC geriatrics. 2016;16:49.
146. Taraldsen K, Thingstad P, Sletvold O, Saltvedt I, Lydersen S, Granat MH, et al. The long-term effect of being treated in a geriatric ward compared to an orthopaedic ward on six measures of free-living physical behavior 4 and 12 months after a hip fracture - a randomised controlled trial. BMC geriatrics. 2015;15:160.
147. Thingstad P, Taraldsen K, Saltvedt I, Sletvold O, Vereijken B, Lamb SE, et al. The long-term effect of comprehensive geriatric care on gait after hip fracture: the Trondheim Hip Fracture Trial--a randomised controlled trial. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2016;27(3):933-42.
148. Heltne M, Saltvedt I, Lydersen S, Prestmo A, Sletvold O, Spigset O. Patterns of drug prescriptions in an orthogeriatric ward as compared to orthopaedic ward: results from the Trondheim Hip Fracture Trial-a randomised clinical trial. European journal of clinical pharmacology. 2017;73(8):937-47.
149. Soong C, Cram P, Chezar K, Tajammal F, Exconde K, Matelski J, et al. Impact of an Integrated Hip Fracture Inpatient Program on Length of Stay and Costs. Journal of orthopaedic trauma. 2016;30(12):647-52.
150. Anderson ME, McDevitt K, Cumbler E, Bennett H, Robison Z, Gomez B, et al. Geriatric Hip Fracture Care: Fixing a Fragmented System. The Permanente journal. 2017;21:16-104.
151. Wallace MA, Hammes A, Rothman MS, Trizno AA, Jones CD, Cumbler E, et al. Fixing a Fragmented System: Impact of a Comprehensive Geriatric Hip Fracture Program on Long-Term Mortality. The Permanente journal. 2019;23.
152. Marcheix PS, Collin C, Hardy J, Mabit C, Tchalla A, Charissoux JL. Impact of orthogeriatric management on the average length of stay of patients aged over seventy five years admitted to hospital after hip fractures. International orthopaedics. 2021;45(6):1431-8.

153. Lin SN, Su SF, Yeh WT. Meta-analysis: Effectiveness of Comprehensive Geriatric Care for Elderly Following Hip Fracture Surgery. Western journal of nursing research. 2020;42(4):293-305.
154. Mukherjee K, Brooks SE, Barraco RD, Como JJ, Hwang F, Robinson BRH, et al. Elderly adults with isolated hip fractures- orthogeriatric care versus standard care: A practice management guideline from the Eastern Association for the Surgery of Trauma. The journal of trauma and acute care surgery. 2020;88(2):266-78.
155. Ho SWL, Phua SKA, Tan BY. Bringing orthogeriatric care for elderly patients with hip fractures to Asia. Lancet Reg Health West Pac. 2022;21:100418.
156. Dreinhöfer KE, Mitchell PJ, Bégué T, Cooper C, Costa ML, Falaschi P, et al. A global call to action to improve the care of people with fragility fractures. Injury. 2018;49(8):1393-7.
157. Ranhoff AH, Saltvedt I, Frihagen F, Raeder J, Maini S, Sletvold O. Interdisciplinary care of hip fractures.: Orthogeriatric models, alternative models, interdisciplinary teamwork. Best practice & research Clinical rheumatology. 2019;33(2):205-26.
158. Ferrara MC, Andreano A, Tassistro E, Rapazzini P, Zurlo A, Volpato S, et al. Three-year National report from the Gruppo Italiano di Ortogeriatria (GIOG) in the management of hip-fractured patients. Aging clinical and experimental research. 2020;32(7):1245-53.
159. Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, Prestmo A, Lamb SE, et al. Effect of in-hospital comprehensive geriatric assessment (CGA) in older people with hip fracture. The protocol of the Trondheim Hip Fracture trial. BMC geriatrics. 2011;11:18.
160. Wyller TB, Watne LO, Torbergsen A, Engedal K, Frihagen F, Juliebo V, et al. The effect of a pre- and post-operative orthogeriatric service on cognitive function in patients with hip fracture. The protocol of the Oslo Orthogeriatrics Trial. BMC geriatrics. 2012;12:36.
161. Edemekong PF BD, Sukumaran S, et al. Activities of Daily Living. In: Publishing; SITIFS, editor. https://www.ncbi.nlm.nih.gov/books/NBK470404/2022.
162. Katz S. Assessing self-maintenance: activities of daily living, mobility, and instrumental activities of daily living. Journal of the American Geriatrics Society. 1983;31(12):721-7.
163. Kingston A, Collerton J, Davies K, Bond J, Robinson L, Jagger C. Losing the ability in activities of daily living in the oldest old: a hierarchic disability scale from the Newcastle 85+ study. PloS one. 2012;7(2):e31665.
164. Bloch F, Thibaud M, Dugué B, Brèque C, Rigaud AS, Kemoun G. Episodes of falling among elderly people: a systematic review and meta-analysis of social and demographic pre-disposing characteristics. Clinics (Sao Paulo). 2010;65(9):895-903.
165. Bentler SE, Liu L, Obrizan M, Cook EA, Wright KB, Geweke JF, et al. The aftermath of hip fracture: discharge placement, functional status change, and mortality. Am J Epidemiol. 2009;170(10):1290-9.
166. Solou K, Tyllianakis M, Kouzelis A, Lakoumentas J, Panagopoulos A. Morbidity and Mortality After Second Hip Fracture With and Without Nursing Care Program. Cureus. 2022;14(3):e23373.
167. Pasco JA, Sanders KM, Hoekstra FM, Henry MJ, Nicholson GC, Kotowicz MA. The human cost of fracture. Osteoporosis international : a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2005;16(12):2046-52.
168. Alexiou KI, Roushias A, Varitimidis SE, Malizos KN. Quality of life and psychological consequences in elderly patients after a hip fracture: a review. Clinical interventions in aging. 2018;13:143-50.
169. González-Zabaleta J, Pita-Fernandez S, Seoane-Pillado T, López-Calviño B, Gonzalez-Zabaleta JL. Dependence for basic and instrumental activities of daily living after hip fractures. Archives of gerontology and geriatrics. 2015;60(1):66-70.

170. Ravensbergen WM, Blom JW, Kingston A, Robinson L, Kerse N, Teh RO, et al. Declining daily functioning as a prelude to a hip fracture in older persons-an individual patient data meta-analysis. Age and ageing. 2022;51(1).
171. Doshi HK, Ramason R, Azellarasi J, Naidu G, Chan WL. Orthogeriatric model for hip fracture patients in Singapore: our early experience and initial outcomes. Archives of orthopaedic and trauma surgery. 2014;134(3):351-7.
172. Wolters U, Wolf T, Stützer H, Schröder T. ASA classification and perioperative variables as predictors of postoperative outcome. Br J Anaesth. 1996;77(2):217-22.
173. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987;40(5):373-83.
174. Alexopoulos GS, Abrams RC, Young RC, Shamoian CA. Use of the Cornell scale in nondemented patients. Journal of the American Geriatrics Society. 1988;36(3):230-6.
175. Alexopoulos GS, Abrams RC, Young RC, Shamoian CA. Cornell Scale for Depression in Dementia. Biol Psychiatry. 1988;23(3):271-84.
176. Vinkers DJ, Gussekloo J, Stek ML, Westendorp RG, Van Der Mast RC. The 15-item Geriatric Depression Scale (GDS-15) detects changes in depressive symptoms after a major negative life event. The Leiden 85-plus Study. International journal of geriatric psychiatry. 2004;19(1):80-4.
177. Pellas J, Damberg M. Accuracy in detecting major depressive episodes in older adults using the Swedish versions of the GDS-15 and PHQ-9. Ups J Med Sci. 2021;126.
178. Wade DT. Measurement in neurological rehabilitation. Current opinion in neurology and neurosurgery. 1992;5(5):682-6.
179. Sainsbury A, Seebass G, Bansal A, Young JB. Reliability of the Barthel Index when used with older people. Age and ageing. 2005;34(3):228-32.
180. Dromerick AW, Edwards DF, Diringer MN. Sensitivity to changes in disability after stroke: a comparison of four scales useful in clinical trials. J Rehabil Res Dev. 2003;40(1):1-8.
181. Gladman JR, Lincoln NB, Adams SA. Use of the extended ADL scale with stroke patients. Age and ageing. 1993;22(6):419-24.
182. Harwood RH, Ebrahim S. The validity, reliability and responsiveness of the Nottingham Extended Activities of Daily Living scale in patients undergoing total hip replacement. Disability and rehabilitation. 2002;24(7):371-7.
183. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. The New England journal of medicine. 1995;332(9):556-61.
184. Hughes CP, Berg L, Danziger WL, Coben LA, Martin RL. A new clinical scale for the staging of dementia. The British journal of psychiatry : the journal of mental science. 1982;140:566-72.
185. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res. 1975;12(3):189-98.
186. Dakhil S. Statistical Analysis Plan - TOO HIP 2017 [Available from: http://folk.uio.no/tbwyller/Statistical_analysis_plan_TOO_HIP.pdf.
187. Gueorguieva R, Krystal JH. Move over ANOVA: progress in analyzing repeated-measures data and its reflection in papers published in the Archives of General Psychiatry. Arch Gen Psychiatry. 2004;61(3):310-7.
188. Petkova E, Teresi J. Some statistical issues in the analyses of data from longitudinal studies of elderly chronic care populations. Psychosom Med. 2002;64(3):531-47.
189. Nagin D. Group-Based Modeling of Development: Harvard University Press; 2009.

190. Lydersen S. Logistic regression with more than two categories. Tidsskrift for den Norske laegeforening : tidsskrift for praktisk medicin, ny raekke. 2022;142(10).
191. Kwak C, Clayton-Matthews A. Multinomial logistic regression. Nurs Res. 2002;51(6):404-10.
192. Wu CY, Chuang LL, Lin KC, Lee SD, Hong WH. Responsiveness, minimal detectable change, and minimal clinically important difference of the Nottingham Extended Activities of Daily Living Scale in patients with improved performance after stroke rehabilitation. Archives of physical medicine and rehabilitation. 2011;92(8):1281-7.
193. Taraldsen K, Thingstad P, Døhl Ø, Follestad T, Helbostad JL, Lamb SE, et al. Short and long-term clinical effectiveness and cost-effectiveness of a late-phase community-based balance and gait exercise program following hip fracture. The EVA-Hip Randomised Controlled Trial. PloS one. 2019;14(11):e0224971.
194. Aarden JJ, van der Esch M, Engelbert RHH, van der Schaaf M, de Rooij SE, Buurman BM. Hip Fractures in Older Patients: Trajectories of Disability after Surgery. The journal of nutrition, health & aging. 2017;21(7):837-42.
195. Stabenau HF, Becher RD, Gahbauer EA, Leo-Summers L, Allore HG, Gill TM. Functional Trajectories Before and After Major Surgery in Older Adults. Ann Surg. 2018;268(6):911-7.
196. Gill TM, Han L, Gahbauer EA, Leo-Summers L, Allore HG. Prognostic Effect of Changes in Physical Function Over Prior Year on Subsequent Mortality and Long-Term Nursing Home Admission. Journal of the American Geriatrics Society. 2018;66(8):1587-91.
197. Banaszak-Holl J, Liang J, Quiñones A, Cigolle C, Lee IC, Verbrugge LM. Trajectories of functional change among long stayers in nursing homes: does baseline impairment matter? Journal of aging and health. 2011;23(5):862-82.
198. Thorngren KG, Norrman PO, Hommel A, Cedervall M, Thorngren J, Wingstrand H. Influence of age, sex, fracture type and pre-fracture living on rehabilitation pattern after hip fracture in the elderly. Disability and rehabilitation. 2005;27(18-19):1091-7.
199. Häkkinen A, Heinonen M, Kautiainen H, Huusko T, Sulkava R, Karppi P. Effect of cognitive impairment on basic activities of daily living in hip fracture patients: a 1-year follow-up. Aging clinical and experimental research. 2007;19(2):139-44.
200. Ranhoff AH, Holvik K, Martinsen MI, Domaas K, Solheim LF. Older hip fracture patients: three groups with different needs. BMC geriatrics. 2010;10:65.
201. Haentjens P, Autier P, Barette M, Venken K, Vanderschueren D, Boonen S. Survival and functional outcome according to hip fracture type: a one-year prospective cohort study in elderly women with an intertrochanteric or femoral neck fracture. Bone. 2007;41(6):958-64.
202. Hershkovitz A, Frenkel Rutenberg T. Are extracapsular and intracapsular hip-fracture patients two distinct rehabilitation subpopulations? Disability and rehabilitation. 2022;44(17):4761-6.
203. Arcolin I, Godi M, Giardini M, Guglielmetti S, Corna S. Does the type of hip fracture affect functional recovery in elderly patients undergoing inpatient rehabilitation? Injury. 2021;52(8):2373-8.
204. Kristensen MT, Foss NB, Ekdahl C, Kehlet H. Prefracture functional level evaluated by the New Mobility Score predicts in-hospital outcome after hip fracture surgery. Acta orthopaedica. 2010;81(3):296-302.
205. Karagiannis A, Papakitsou E, Dretakis K, Galanos A, Megas P, Lambiris E, et al. Mortality rates of patients with a hip fracture in a southwestern district of Greece: ten-year follow-up with reference to the type of fracture. Calcified tissue international. 2006;78(2):72-7.
206. Stacey J, Bush C, DiPasquale T. The hidden blood loss in proximal femur fractures is sizeable and significant. J Clin Orthop Trauma. 2021;16:239-43.

207. Mautalen CA, Vega EM, Einhorn TA. Are the etiologies of cervical and trochanteric hip fractures different? Bone. 1996;18(3 Suppl):133s-7s.
208. Holvik K, Ranhoff AH, Martinsen MI, Solheim LF. Predictors of mortality in older hip fracture inpatients admitted to an orthogeriatric unit in oslo, norway. Journal of aging and health. 2010;22(8):1114-31.

Paper I-III

I

https://doi.org/10.1186/s12877-021-02152-7

BMC Geriatrics

RESEARCH ARTICLE Open Access

Orthogeriatrics prevents functional decline in hip fracture patients: report from two randomized controlled trials

Shams Dakhil[1,2*], Pernille Thingstad[3], Frede Frihagen[4], Lars Gunnar Johnsen[3,5,6], Stian Lydersen[7], Eva Skovlund[8],
Torgeir Bruun Wyller[1,2], Olav Sletvold[3,9], Ingvild Saltvedt[3,9] and Leiv Otto Watne[1]

Abstract

Background: The incidence of hip fractures are expected to increase in the following years. Hip fracture patients have in addition to their fracture often complex medical problems, which constitute a substantial burden on society and health care systems. It is thus important to optimize the treatment of these patients to reduce negative outcomes. The aim of this study was to assess the effect of comprehensive orthogeriatric care (CGC) on basic and instrumental activities of daily living (B-ADL and I-ADL).

Methods: This study is based on two randomized controlled trials; the Oslo Orthogeriatric Trial and the Trondheim Hip Fracture Trial. The two studies were planned in concert, and data were pooled and analyzed using linear mixed models. I-ADL function was assessed by the Nottingham Extended ADL Scale (NEADL) and B-ADL by the Barthel ADL (BADL) at four and twelve months after surgery.

Results: Seven hundred twenty-six patients were included in the combined database, of which 365 patients received OC and 361 patients received CGC. For the primary endpoint, I-ADL at four months was better in the CGC group, with a between-group difference of 3.56 points (95 % CI 0.93 to 6.20, $p = 0.008$). The between-group difference at 12 months was 4.28 points (95 % CI 1.57 to 7.00, $p = 0.002$). For B-ADL, between-group difference scores were only statistically significant at 12 months. When excluding the patients living at a nursing home at admission, both I-ADL and B-ADL function was significantly better in the CGC group compared to the OC group at all time points.

Conclusions: Merged data of two randomized controlled trials showed that admitting hip fracture patients to an orthogeriatric care unit directly from the emergency department had a positive effect on ADL up to twelve months after surgery.

Keywords: Orthogeriatric, Hip fracture, Activities of Daily living (ADL)

* Correspondence: shams.dakhil@studmed.uio.no
[1]Department of Geriatric Medicine, Oslo University Hospital, Oslo, Norway
[2]Institute of Clinical Medicine, University of Oslo, Oslo, Norway
Full list of author information is available at the end of the article

Background

Patients suffering from a hip fracture are often frail; suffering multiple comorbidities, and are often subjected to polypharmacy [1]. The prefracture functional level of hip fracture patients has been found to be a strong and consistent predictor of short- and long-term rehabilitation outcome [2]. Only one third of patients return to their prefracture function, and one third will require further nursing home care [3]. Since the incidence is expected to increase, hip fractures will become a progressively larger public health burden [4–6].

Hip fracture patients are a large and resourcedemanding group. Several studies have shown that orthogeriatric care is beneficial regarding length of stay in hospital, waiting time to surgery, fewer surgical and medical complications and survival [7–15]. There are several different orthogeriatric models; ranging from orthopedic wards with a geriatric consultant service to an integrated care ward [7]. However, due to the heterogeneity of the different studies both in measured outcomes and study design, it is challenging to draw conclusions on what type of orthogeriatric care model is superior. In addition, most studies have evaluated the effect based on register data (mortality, length of stay, readmissions) and very few have assessed the effect based on a face-to-face evaluation of the patients in the months following discharge.

It has been argued that hip fracture patients benefit from an admission to a geriatric ward instead of an orthopedic ward [8, 16–19]. In such a model, “Geriatric and rehabilitation ward and orthopedic consultant service” according to Kammerlander [7], the patient is admitted directly from the emergency department to the geriatric ward. The patient has the entire stay (except for surgery) in the geriatric ward, and the orthopedics serve as consultants. Several studies have evaluated the effect of the implementation of such a model and the overall impression is that it is beneficial [20–24]. However, due to the heterogeneity in study design and outcomes, there is a need for multi-center studies which will allow for increased generalizability and give more precise estimates of the effect of such models.

Recently there have been two randomized controlled trials (RCTs) in Norway assessing the effect of this model; The Trondheim Hip Fracture Trial [25] and the Oslo Orthogeriatric Trial [1]. In both studies, the control group received traditional orthopedic care. The Oslo and Trondheim studies were planned in concert, and we have now merged data from these studies. This pooled data set will yield information from a larger and more heterogeneous group of hip fracture patients and increased statistical power will give more precise estimates of the effect of the model. The aim of the current study was to assess the effect of our orthogeriatric model on Activities of Daily Living (ADL) – both instrumental ADL (I-ADL) and basic ADL (B-ADL) - four and twelve months after surgery.

Methods

Inclusion and randomization took place in the emergency department in the respective hospitals in both trials. In Oslo randomization was based on computergenerated random numbers (blocks of variable and unknown size) and was carried out by a statistician not involved in the clinical service. Randomization was also stratified according to whether or not the patients were admitted from nursing homes. In Trondheim patients were randomly assigned in a 1:1 ratio by a nurse. In both hospitals patients were transferred to the allocated wards directly from the emergency department. The intervention group received a CGC service preoperatively as well as postoperatively. Surgical and anesthesiologic procedures were similar in both groups. Four- and twelvemonth follow-up assessments were carried out at the hospital by study nurses blinded to group allocation. If the patients were unable to visit the hospitals the study nurses visited the patients where they were living at the specific time point and conducted the follow-up interview face to face. Since the intervention was at ward level, data collection during the index stay could not be blinded.

Oslo orthogeriatric trial

Recruitment lasted from September 2009 to January 2012 at Oslo University Hospital. All hip fracture patients were eligible for the trial, unless if the fracture was due to a high-energy trauma or if the patient was moribund at admission. Both home-dwelling patients and patients living in a nursing home at admission, at all ages were included, in total 329 patients [1].

Patients randomized to intervention were treated in the acute geriatric ward; both pre- and postoperatively. A team consisting of a geriatrician, nurse, physiotherapist and occupational therapist were responsible for delivering the CGC service. They were expected to assess patients during their first day on the ward, as well as conducting daily meetings to coordinate treatment and to plan discharge. The CGC service included medication reviews, early and intensive mobilization, optimizing pre- and postoperative nutrition and early discharge planning. Details about the clinical routines have been published [26].

The primary outcome for this study was cognitive function four months after surgery, and the secondary outcomes included delirium, delirium severity, length of stay, mortality, mobility, place of residence, Instrumental (I-ADL) and basic (B-ADL) function, and weight changes. The intervention had no impact on the primary outcome. However, better mobility (measured by the Short Physical Performance Battery (SPPB [27]) was found in home-dwelling patients [1].

Trondheim hip fracture trial

Recruitment lasted from April 2008 to December 2010 at St. Olavs Hospital, Trondheim University hospital. All home-dwelling patients above the age of 70, and who were able to walk 10 m or more before the fracture were included (n = 397). Patients that had suffered a pathological fracture, undergone multiple traumas, or had a short life expectancy, as well as patients already living in a nursing home were excluded [25].

Patients randomized to intervention were treated in the geriatric ward with CGC service; both pre- and postoperatively. The CGC service included comprehensive medical assessment and treatment, early rehabilitation and early planning of discharge. Details about the clinical routines have been published [28].

For this study the primary outcome was mobility after four months measured by the SPPB, and secondary outcomes included I-ADL, B-ADL, cognition, quality of life, fear of falling, depression, gait control and daily physical activity. The study found a positive effect of the intervention on the primary outcome, and also on several of the secondary outcomes (I-ADL, B-ADL, fear of falling, quality of life, gait control and daily physical activity) [25].

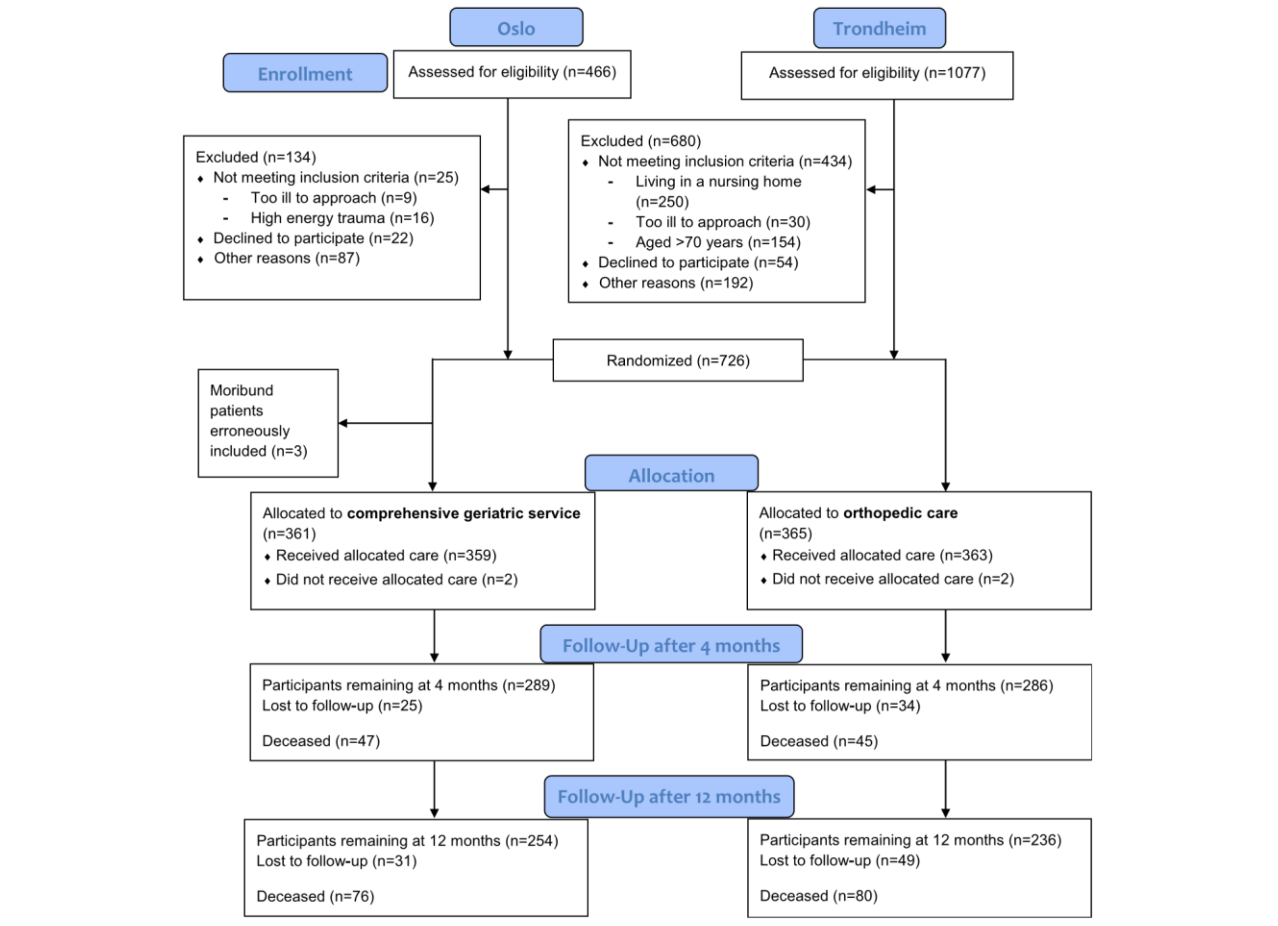

Fig. 1 Consort flow diagram

TOO HIP (the OslO and Trondheim HIP fracture trial) database

The Trondheim Hip Fracture Trial and the Oslo Orthogeriatrics Trial were planned in concert, and similar design and outcomes were chosen for future pooling of data as described in their protocols [26, 29]. The goal was to make a larger and more heterogeneous database to provide the opportunity for more precise estimates on outcomes (Fig. 1). For assessing the effect of intervention on I-ADL and B-ADL function in the combined dataset, Nottingham Extended Activities of Daily Living Scale (NEADL) (range 0–66, higher scores indicate better function) [30] four months after surgery was chosen as the primary outcome. Secondary outcomes included NEADL at twelve months postoperatively, The Barthel ADL Index (BADL) (measures degree of independence in ten basic ADL functions (range 0–20), higher scores indicate better function) [31] score at four and twelve months postoperatively, intra-hospital mortality and cumulative mortality at four and twelve months postoperatively, and new nursing home admissions.

Statistical methods

A statistical analysis plan was completed prior to any analyses [32]. The primary efficacy analysis was carried out using linear mixed model with NEADL as dependent variable, patient as random factor, time point (baseline, four months and twelve months) as fixed factor, and treatment group, site (Oslo versus Trondheim), age, sex, fracture type (extracapsular versus intracapsular), dwelling at home (versus nursing home), and the interaction between time points after inclusion and treatment group as covariates. Similar mixed model analyses were carried out with BADL score as the dependent variable. Dichotomous outcomes were analysed unadjusted, comparing proportions in the two treatment groups. In addition, they were compared using logistic regression, unadjusted, and adjusted for site, age, sex, fracture type and dwelling at home.

A two-sided p-value below 0.05 was taken as an indicator of statistical significance, and 95 % confidence intervals (CI) are reported where relevant. Missing items within the NEADL and BADL scales were imputed by the mean score for the remaining items that were answered, if at least 80 % of the items on the scale were answered. Normality of residuals was checked by visual inspection of Q-Q-plots. All statistical analyses were done using IBM SPSS statistics 22–25.

Results

In total 726 patients were included in the combined database, of which 365 patients received traditional OC and 361 patients received CGC. Baseline characteristics did not differ between the groups (Table 1). Mean age was 83.0 years (SD 7.7), 542 (74.7 %) were women, and 102 (14.0 %) were living in a nursing home at admission. The groups were similar in function as measured by NEADL and BADL at baseline.

At four months the CGC group had better mean NEADL scores than the OC group with a betweengroup difference of 3.56 points (CI 0.93 to 6.20, p = 0.008; Table 2). The between-group difference at twelve months was 4.28 points (CI 1.57 to 7.00, p = 0.002; Table 2).

For BADL; between-group difference scores were in favor of CGC on four and twelve months, but were only statistically significant at 12 months (4 month: betweengroup difference at 0.34 and CI 0.25 to 0.94, p = 0.26,

Table 1 Baseline characteristics

	Comprehensive geriatric care (N = 361)	Orthopedic care (N = 365)
Age, mean (SD)	83.0 (7.3)	83.0 (8.0)
Male (%)	95 (26.3)	89 (24.4)
Living in a nursing home at admission (%)[a]	52 (14.4)	50 (13.7)
Barthel Index, mean (SD)[b]	17.2 (3.7)	17.4 (3.6)
NEADL, mean (SD)[c]	37.1 (20.6)	37.5 (19.9)
Type of fracture - Extracapsular (%)	144 (39.9)	141 (38.6)
- Intracapsular (%)	217 (60.1)	224 (61.4)
Surgical treatment[d] - Hemiarthroplasty (%)	148 (41.2)	155 (42.8)
- Osteosynthesis (%)	208 (57.95)	199 (55.0)
- Total hip replacement (%)	2 (0.6)	5 (1.4)
- Girdlestone (%)	1 (0.3)	0 (0)
- Not operated (%)	0 (0)	3 (0.8)
- Died before surgery	2 (0.6)	3 (0.8)
Injury occurred indoors (%)[e]	270 (77.6)	279 (78.8)

SD standard deviation, Barthel Index Barthel Index for Activities of Daily Living, NEADL Nottingham Extended Activities of Daily Living [a]Patients admitted from nursing homes were excluded in Trondheim [b]Barthel Index was missing from 10 in the orthopedic care group and 6 patients in the comprehensive geriatric care group [c]NEADL was missing from 12 patients in the orthopedic care group and 9 patients in the comprehensive geriatric care group [d]Information about surgical treatment was missing/unknown in 3 patients in the orthopedic care group and 2 patients in the comprehensive geriatric care group
[e]Information about where the injury occurred (inside/outside) was unknown in 11 patients in the orthopedic care group and 13 patients in the comprehensive geriatric care group

and 12 months: between-group difference at 0.68 and CI 0.05 to 1.31, p = 0.034; Table 2).

When excluding the patients living at a nursing home at baseline, the ADL function was better in the intervention group at all time points; both for NEADL (4 months: between-group difference at 4.56 and CI 1.61 to 7.52, p =

0.003 and twelve months: between-group difference at 5.41 and CI 2.38 to 8.44, p < 0.001; Table 3) and for BADL (four months: between-group difference at 0.67 and CI 0.06 to 1.28, p = 0.030 and twelve months: between-group difference at 0.97 and CI 0.34 to 1.60, p = 0.003; Table 3).

The mean preoperative waiting time was not different between groups (30.5 vs. 29.2 h, p = 0.76; Table 4). Length of hospital stay was longer in the CGC group (mean 12.8 vs. 9.8 days p < 0.001; Table 4). In-hospital mortality was the same between the groups (2.2 vs. 2.2 %, p = 0.98; Table 4). Also, there was no significant difference in number of deaths at 4 months (13.0 vs. 12.3 %, p = 0.78) or 12 months (20.8 vs. 21.6 %, p = 0.78) after surgery. There was a trend towards fewer new nursing home admissions in the CGC group at 4 months (16.9 vs. 20.9 %, p = 0.23) and 12 months (19.2 vs. 25.3 %, p = 0.11; Table 4).

Table 2 Linear mixed model with NEADL and Barthel Index

	Comprehensive geriatric care		Orthopedic care		Difference	
	N	Mean (SE)	N	Mean (SE)	Estimate (95 % CI)	p-value
4 months	295		291			
NEADL[a]	281	30.34 (0.95)	276	26.77 (0.95)	3.56 (0.93 to 6.20)	0.008
Barthel Index[b]	286	15.44 (0.22)	284	15.09 (0.22)	0.34 (-0.25 to 0.94)	0.26
12 months	260		245			
NEADL[c]	253	30.59 (0.97)	234	26.31 (0.99)	4.28 (1.57 to 7.00)	0.002
Barthel Index[d]	251	15.46 (0.22)	234	14.78 (0.23)	0.68 (0.05 to 1.31)	0.034

Linear mixed model with NEADL and Barthel Index, respectively, as dependent variable, patient as random factor, time point (baseline, 4 months and 12 months after surgery) as fixed factor, and treatment group, site (Oslo versus Trondheim), age, sex, fracture type, dwelling at home (versus nursing home), and the interaction between time and treatment as covariates

SE standard error, CI confidence interval, NEADL Nottingham Extended Activities of Daily Living scale, Barthel Index Barthel Activities of Daily Living index

[a] NEADL at 4 months missing from 15 patients in the orthopedic care group and 14 patients in the comprehensive geriatric care group

[b] Barthel Index at 4 months missing from 7 patients in the orthopedic care group and from 9 patients in the comprehensive geriatric care group

[c] NEADL at 12 months missing from 11 patients in the orthopedic care group and 7 patients in the comprehensive geriatric care group

[d] Barthel Index at 12 months missing from 11 patients in the orthopedic care group and missing 9 patients in the comprehensive geriatric care group

Discussion

The present study merged data from two Norwegian RCTs evaluating impact of CGC performed in acute geriatric wards compared to usual care in orthopaedic wards in treatment of hip-fracture patients. Our main result is that I-ADL was better in hip fracture patients treated with CGC as compared to usual care four and twelve months post-operatively. B-ADL as well, was better in the intervention group after twelve months. The effect of intervention on I-ADL and B-ADL was stronger when excluding patients admitted from a nursing home. A difference of 2.4 points on NEADL is considered to be clinically significant [33] and one point on BADL is the difference between being independent or not in basic ADL functions (walking, feeding, toilet use etc.). We therefore believe that the effects we find in our study is clinically relevant.

Our findings are in line with other studies conducted on a similar orthogeriatric care model as ours. In a quasi-RCT, Adunsky et al. showed that patients allocated to the intervention arm had almost a two-fold chance of successful rehabilitation outcome defined as more than 50 % increase in “relative functional gain” [23]. Stenvall et al., conducted a prospective RCT and showed that significantly more patients allocated to intervention had regained independence in both I-ADL and B-ADL performance both four and twelve months after surgery, measured by the Katz Index of Independence in ADL [24]. To our knowledge these are the only other studies conducted in a geriatric ward with ADL as an end point. Other studies conducted in an orthopedic ward with varying geriatric liaison service have also evaluated the

Table 3 ADL excluding nursing home patients

	Comprehensive geriatric care	Mean (SE)	Orthopedic care	Mean (SE)	Difference

	N		N		Estimate (95 % CI)	p-value
4 months	260		253			
NEADL[a]	247	33.88 (1.06)	241	29.31 (1.07)	4.56 (1.61 to 7.52)	0.003
Barthel Index[b]	251	16.54 (0.22)	247	15.87 (0.22)	0.67 (0.06 to 1.28)	0.030
12 months	234		217			
NEADL[c]	227	34.33 (1.08)	208	28.92 (1.10)	5.41 (2.38 to 8.44)	< 0.001
Barthel Index[d]	226	16.59 (0.23)	207	15.62 (0.23)	0.97 (0.34 to 1.60)	0.003

Linear mixed model with NEADL and Barthel Index, respectively, as dependent variable, patient as random factor, time point (baseline, 4 months and 12 months after surgery) as fixed factor, and treatment group, site (Oslo versus Trondheim), age, sex, fracture type, dwelling at home (versus nursing home), and the interaction between time and treatment as covariates

SE standard error, 95 % CI 95 % confidence interval, NEADL Nottingham Extended Activities of Daily Living scale, Barthel Index Barthel Activities of Daily Living index

[a] NEADL at 4 months missing from 12 patients in the orthopedic care group and 13 patients in the comprehensive geriatric care group

[b] Barthel Index at 4 months missing from 6 patients in the orthopedic care group and from 9 patients in the comprehensive geriatric care group

[c] NEADL at 12 months missing from 9 patients in the orthopedic care group and 7 patients in the comprehensive geriatric care group

[d] Barthel Index at 12 months missing from 10 patients in the orthopedic care group and missing 8 patients in the comprehensive geriatric care group

Table 4 Impact of intervention during hospital stay, and 4 months and 12 months after hospital stay

Hospital stay	Comprehensive geriatric care (N = 361)	Orthopedic care (N = 365)	p-value
Waiting time for surgery in hours, mean (SD)[a]	30.5 (26.8)	29.2 (19.1)	0.76[1]
Length of stay in days, mean (SD)	12.8 (7.9)	9.8 (6.7)	< 0.001[1]
In-hospital mortality (%)	8 (2.2)	8 (2.2)	0.98[2]
4 months after surgery	Comprehensive geriatric care (N = 295)	Orthopedic care (N = 291)	
New nursing home admissions (%)[b]	44 (16.9)	53 (20.9)	0.23[2]
12 months after surgery	Comprehensive geriatric care (N = 260)	Orthopedic care (N = 245)	
New nursing home admissions (%)[b]	45 (19.2)	55 (25.3)	0.11[2]

SD standard deviation

[a] Waiting time for surgery in hours, defined as hours from admission to start of anesthesia, missing from 7 patients in the orthopaedic care group and 2 patients in the comprehensive geriatric care group [b] Information about new nursing home admissions missing/unknown in 2 patients in the orthopedic care group at 4 months, and 1 patient in the orthopedic care group at 12 months. Fifty patients from the orthopedic care group and fifty-two patients from the geriatric care group lived in a nursing home before the

hip fracture
[1]Mann-Whitney U Test
[2]Pearson Chi-Square test

effect of intervention on ADL; some have shown an effect of intervention [9, 19, 34–37], while others have only shown a trend [38] or no effect [39, 40].

The mean length of hospital stay was significantly longer in the intervention group in our study. A reduction of length of stay is often considered costeffective [41–44]. However, in addition to costs of the initial hospitalization there are several other aspects, such as re-admissions and need of rehabilitation and nursing homes. If longer length of stay results in increased ADL function it might therefore be beneficial for the society in the long run, as was also the conclusion in the Trondheim Hip Fracture Trial that calculated the full cost the first year after the hip fracture.

No other secondary outcome was significantly different between treatment groups in our study, including mortality, preoperative waiting time, and number of patients living in a nursing home four and twelve months after surgery. Some studies have reported reduced mortality after the introduction of orthogeriatric care [8, 10–16]. The lack of effect on mortality in our study can be due to the fact that the mortality, compared to other studies, was already low before implementation of the orthogeriatric model [16].

Due to inclusion criteria, the Oslo study included more frail patients than the Trondheim study. We thus chose to include site (Oslo vs. Trondheim) as a covariate in the statistical analysis to correct for this.

When excluding the patients admitted from a nursing home, the effect of the intervention on ADL was stronger. One possible explanation is that the frailest patients already have lost much function and the potential for reduction of further decline therefore is limited. This does not mean that these patients do not benefit of orthogeriatric care, but other instruments than the ADL scales we have used might be better to evaluate the effect (quality of life, satisfaction among patients/carers). The more fit patients in our study benefitted the most. An interpretation is that those with best function are most prone to functional decline and that optimized care therefore is particularly important in this group. A concrete strategy based on these findings would be to categorize hip fracture patients already at admission into groups based on where they realistically could be discharged (e.g. (1) Home, (2) Rehabilitation. (3) Nursing home). Tailored intervention based on these groups might be a way to optimize use of resources and at the same time secure that patients with the largest potential for rehabilitation are prioritized, a strategy in line with recommendations based on register data on hip fracture patients in Norway [45].

Strengths and limitations

A strength of this study is the randomized controlled design of the included studies and the large sample size. Furthermore, both studies were planned in concert with future pooling of data in mind. Another strength is that patients were evaluated face to face by research nurses blinded to allocation four and twelve months after surgery. The wide inclusion criteria allowed for a heterogeneous study population and increase the generalizability of our findings. The different age distribution and differences regarding nursing home residents were accounted for by adjusting for these variables in the analyses, so we do not regard this as a limitation in the study. A limitation of the study is the lack of masking of both the patients and the staff delivering the treatment.

Conclusions

Merged data of two RCTs conducted in Norway showed that administration of comprehensive geriatric care to hip fracture patients in an acute geriatric ward had a positive effect on I-ADL and B-ADL up to twelve months after surgery. The effect was strongest in homedwelling patients.

Abbreviations

RCTs: Randomized Controlled Trials; ADL: Activities of Daily Living; IADL: Instrumental Activities of Daily Living; B-ADL: Basic Activities of Daily Living; CGC: Comprehensive Geriatric Care; OC: Orthopedic Care;
CGA: Comprehensive Geriatric Assessment; SPPB: Short Physical Performance
Battery; NEADL: Nottingham Extended Activities of Daily Living; BADL: The Barthel ADL Index; CI: Confidence Intervals

Acknowledgements

The authors would like to thank the patients and staff at the Orthopedic Department and the Geriatric Department at Oslo University Hospital and St. Olavs Hospital, Trondheim University hospital. They also thank research nurses Elisabeth Fragaat, Tone Fredriksen, Camilla Marie Andersen, Julie Ask Ottesen and Linda Feldt for assisting in data collection. Further we want to thank members of the study group in Trondheim especially Jorunn Helbostad, Anders Prestmo, Kristin Taraldsen and Sarah Lamb for their valid contribution in planning and performing the Trondheim part of the study.

Authors' contributions
SD combined the two datasets, analyzed an interpreted all patient data and prepared the manuscript. SL analyzed an interpreted all patient data, as well as preparing the "Statistical Methods" section and reviewing the manuscript. ES assisted in interpreting the data and reviewing the manuscript. LOW, TBW, IS, OS, PT, FF and LGJ designed, conducted and collected data from the trials, assisted in interpreting all patients data, as well as preparing and reviewing the manuscript. The author(s) read and approved the final manuscript.

Funding
The Oslo Orthogeriatric Trial was mainly funded by the Research Council of Norway. The Trondheim hip fracture study was funded by the Norwegian Research Council, the Central Norway Health Authority, the St. Olav Hospital Trust, the Department of Neuromedicine and Movement science, NTNU, the SINTEF and St. Olav Hospital Fund for Research and Innovation, and the Municipality of Trondheim. The sponsors had no role in the design and conduct of the study or methods, the collection, management, analysis, and interpretation of the data, or the preparation, review, and approval of the manuscript.

Availability of data and materials
The data that support the findings of this study are available on request from the corresponding author.

Declarations

Ethics approval and consent to participate
The Oslo Orthogeriatric Trial was registered with ClinicalTrials.gov (NCT01009268), and approved by the Regional Committee for Ethics in Medical Research in South East of Norway (REK 2009/450). The Trondheim Hip Fracture Trial was registered with ClinicalTrials.gov (NCT00667914), and approved by the Regional Committee for Ethics in Medical Research in Central Norway (REK4.2008.335). The Regional Committee for Ethics in Medical Research in South East of Norway and the Data Protection Officer at both hospitals approved merging of data from the two separate trials. Both studies were conducted in accordance with the Declaration of Helsinki. The patients or a proxy gave informed written consent to be included in the study before participation in both trials.

Consent for publication Not applicabale.
Competing interests
I. Saltvedt has performed Alzheimer drug trial for Boehringer-Ingelheim 1346.0023. The remaining authors declare that they have no competing interests.

Author details
[1] Department of Geriatric Medicine, Oslo University Hospital, Oslo, Norway. [2] Institute of Clinical Medicine, University of Oslo, Oslo, Norway. [3] Department of Neuromedicine and Movement Science, Norwegian University of Science and Technology (NTNU), Trondheim, Norway. [4]Division of Orthopedic Surgery, Oslo University Hospital, Oslo, Norway. [5]Orthopedic Trauma Unit, Department of Orthopedic Surgery, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Norway. [6]Norwegian National Advisory Unit on Trauma, Division of Emergencies and Critical Care, Oslo University Hospital, Oslo, Norway. [7]Department of Mental Health, Regional Centre for Child and Youth Mental Health and Child Welfare, Norwegian University of Science and Technology (NTNU), Trondheim, Norway. [8]Department of Public Health and Nursing, Norwegian University of Science and Technology (NTNU), Trondheim, Norway. [9]Department of Geriatrics, St. Olavs Hospital, Trondheim University Hospital, Trondheim, Norway.

Received: 3 September 2020 Accepted: 14 March 2021
Published online: 25 March 2021

References
1. Watne LO, Torbergsen AC, Conroy S, Engedal K, Frihagen F, Hjorthaug GA, et al. The effect of a pre- and postoperative orthogeriatric service on cognitive function in patients with hip fracture: randomized controlled trial (Oslo Orthogeriatric Trial). BMC Med. 2014;12:63.
2. Kristensen MT. Factors affecting functional prognosis of patients with hip fracture. Eur J Phys Rehabil Med. 2011;47(2):257–64.
3. Kammerlander C, Doshi HK, Bocker W, Gosch M. Fragility Fracture Care and Orthogeriatric Comanagement. BioMed research international. 2016;2016: 2056376.
4. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. Injury. 2018;49(8):1458–60.
5. Cheng SY, Levy AR, Lefaivre KA, Guy P, Kuramoto L, Sobolev B. Geographic trends in incidence of hip fractures: a comprehensive literature review. Osteoporosis Int. 2011;22(10):2575–86.
6. Hernlund E, Svedbom A, Ivergard M, Compston J, Cooper C, Stenmark J, et al. Osteoporosis in the European Union: medical management, epidemiology and economic burden. A report prepared in collaboration with the International Osteoporosis Foundation (IOF) and the European Federation of Pharmaceutical Industry Associations (EFPIA). Arch Osteo. 2013;8:136.
7. Kammerlander C, Roth T, Friedman SM, Suhm N, Luger TJ, KammerlanderKnauer U, et al. Ortho-geriatric service–a literature review comparing different models. Osteo Int. 2010;21(Suppl 4):S637-46.
8. Grigoryan KV, Javedan H, Rudolph JL. Orthogeriatric care models and outcomes in hip fracture patients: a systematic review and meta-analysis. J Orthop Trauma. 2014;28(3):e49–55.
9. Lin SN, Su SF, Yeh WT. Meta-analysis: Effectiveness of Comprehensive Geriatric Care for Elderly Following Hip Fracture Surgery. West J Nurs Res. 2020;42(4):293–305.

10. Stenqvist C, Madsen CM, Riis T, Jorgensen HL, Duus BR, Lauritzen JB, et al. Orthogeriatric Service Reduces Mortality in Patients With Hip Fracture. Geriatric orthopaedic surgery rehabilitation. 2016;7(2):67–73.
11. Barone A, Giusti A, Pizzonia M, Razzano M, Palummeri E, Pioli G. A comprehensive geriatric intervention reduces short- and long-term mortality in older people with hip fracture. J Am Geriatr Soc. 2006;54(7): 1145–7.
12. Folbert EC, Hegeman JH, Vermeer M, Regtuijt EM, van der Velde D, Ten Duis HJ, et al. Improved 1-year mortality in elderly patients with a hip fracture following integrated orthogeriatric treatment. Osteo Int. 2017;28(1):269–77.
13. Henderson CY, Shanahan E, Butler A, Lenehan B, O'Connor M, Lyons D, et al. Dedicated orthogeriatric service reduces hip fracture mortality. Ir J Med Sci. 2017;186(1):179–84.
14. Suarez S, Pesantez RF, Diaz ME, Sanchez D, Tristancho LJ, Vanegas MV, et al. Impact on Hip Fracture Mortality After the Establishment of an Orthogeriatric Care Program in a Colombian Hospital. J Aging Health. 2017; 29(3):474–88.
15. Zeltzer J, Mitchell RJ, Toson B, Harris IA, Ahmad L, Close J. Orthogeriatric services associated with lower 30-day mortality for older patients who undergo surgery for hip fracture. The Medical journal of Australia. 2014; 201(7):409–11.
16. Moyet J, Deschasse G, Marquant B, Mertl P, Bloch F. Which is the optimal orthogeriatric care model to prevent mortality of elderly subjects post hip fractures? A systematic review and meta-analysis based on current clinical practice. Int Orthop. 2019;43:1449–54.
17. Sabharwal S, Wilson H. Orthogeriatrics in the management of frail older patients with a fragility fracture. Osteo Int. 2015;26(10):2387–99.
18. Shields L, Henderson V, Caslake R. Comprehensive Geriatric Assessment for Prevention of Delirium After Hip Fracture: A Systematic Review of Randomized Controlled Trials. J Am Geriatr Soc. 2017;65(7):1559–65.
19. Mukherjee K, Brooks SE, Barraco RD, Como JJ, Hwang F, Robinson BRH, et al. Elderly adults with isolated hip fractures- orthogeriatric care versus standard care: A practice management guideline from the Eastern Association for the Surgery of Trauma. J Traum Acute Care Surg. 2020;88(2):266–78.
20. Boyd RV, Hawthorne J, Wallace WA, Worlock PH, Compton EH. The Nottingham orthogeriatric unit after 1000 admissions. Injury. 1983;15(3):193–6.
21. Miura LN, DiPiero AR, Homer LD. Effects of a geriatrician-led hip fracture program: improvements in clinical and economic outcomes. J Am Geriatr Soc. 2009;57(1):159–67.
22. Adunsky A, Lerner-Geva L, Blumstein T, Boyko V, Mizrahi E, Arad M. Improved survival of hip fracture patients treated within a comprehensive geriatric hip fracture unit, compared with standard of care treatment. J Am Med Dir Assoc. 2011;12(6):439–44.
23. Adunsky A, Lusky A, Arad M, Heruti RJ. A comparative study of rehabilitation outcomes of elderly hip fracture patients: the advantage of a comprehensive orthogeriatric approach. J Gerontol Series A Biol Sci Med Sci. 2003;58(6):542–7.
24. Stenvall M, Olofsson B, Nyberg L, Lundstrom M, Gustafson Y. Improved performance in activities of daily living and mobility after a multidisciplinary postoperative rehabilitation in older people with femoral neck fracture: a randomized controlled trial with 1-year follow-up. J Rehabil Med. 2007;39(3): 232–8.
25. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, et al. Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet. 2015;385(9978):1623–33.
26. Wyller TB, Watne LO, Torbergsen A, Engedal K, Frihagen F, Juliebo V, et al. The effect of a pre- and post-operative orthogeriatric service on cognitive function in patients with hip fracture. The protocol of the Oslo Orthogeriatrics Trial. BMC Geriatr. 2012;12:36.
27. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lowerextremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med. 1995;332(9):556–61.
28. Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, Prestmo A, Lamb SE, et al. Effect of in-hospital comprehensive geriatric assessment (CGA) in older people with hip fracture. The protocol of the Trondheim Hip Fracture trial. BMC Geriatr. 2011;11:18.
29. Saltvedt I, Prestmo A, Einarsen E, Johnsen LG, Helbostad JL, Sletvold O. Development and delivery of patient treatment in the Trondheim Hip Fracture Trial. A new geriatric in-hospital pathway for elderly patients with hip fracture. BMC Res Notes. 2012;5:355.
30. Gladman JR, Lincoln NB, Adams SA. Use of the extended ADL scale with stroke patients. Age Ageing. 1993;22(6):419–24.
31. Wade DT. Measurement in neurological rehabilitation. Curr Opin Neurol Neurosurg. 1992;5(5):682–6.
32. Dakhil S. Statistical Analysis Plan - TOO HIP 2017 [Available from: http://folk. uio.no/tbwyller/Statistical_analysis_plan_TOO_HIP.pdf.
33. Wu CY, Chuang LL, Lin KC, Lee SD, Hong WH. Responsiveness, minimal detectable change, and minimal clinically important difference of the Nottingham Extended Activities of Daily Living Scale in patients with improved performance after stroke rehabilitation. Arch Phys Med Rehabil. 2011;92(8):1281–7.
34. Shyu YI, Liang J, Wu CC, Su JY, Cheng HS, Chou SW, et al. Interdisciplinary intervention for hip fracture in older Taiwanese: benefits last for 1 year. J Gerontol Series A Biol Sci Med Sci. 2008;63(1):92–7.
35. Shyu YI, Liang J, Wu CC, Su JY, Cheng HS, Chou SW, et al. Two-year effects of interdisciplinary intervention for hip fracture in older Taiwanese. J Am Geriatr Soc. 2010;58(6):1081–9.
36. Shyu YI, Liang J, Wu CC, Su JY, Cheng HS, Chou SW, et al. A pilot investigation of the short-term effects of an interdisciplinary intervention program on elderly patients with hip fracture in Taiwan. J Am Geriatr Soc. 2005;53(5):811–8.
37. Doshi HK, Ramason R, Azellarasi J, Naidu G, Chan WL. Orthogeriatric model for hip fracture patients in Singapore: our early experience and initial outcomes. Arch Orthop Trauma Surg. 2014;134(3):351–7.
38. Vidan M, Serra JA, Moreno C, Riquelme G, Ortiz J. Efficacy of a comprehensive geriatric intervention in older patients hospitalized for hip fracture: a randomized, controlled trial. J Am Geriatr Soc. 2005;53(9):1476–82.
39. Deschodt M, Braes T, Broos P, Sermon A, Boonen S, Flamaing J, et al. Effect of an inpatient geriatric consultation team on functional outcome, mortality, institutionalization, and readmission rate in older adults with hip fracture: a controlled trial. J Am Geriatr Soc. 2011;59(7):1299–308.
40. Swanson CE, Day GA, Yelland CE, Broome JR, Massey L, Richardson HR, et al. The management of elderly patients with femoral fractures. A randomised controlled trial of early intervention versus standard care. The Medical journal of Australia. 1998;169(10):515–8.
41. Elliot JR, Wilkinson TJ, Hanger HC, Gilchrist NL, Sainsbury R, Shamy S, et al. The added effectiveness of early geriatrician involvement on acute orthopaedic wards to orthogeriatric rehabilitation. N Z Med J. 1996; 109(1017):72–3.
42. Leung FK, Lau TW, Yuen GW, Chan EM, Chan P, Lam RY. Effectiveness of a multidisciplinary approach to geriatric hip fractures in improving clinical outcomes and cost of care. Hong Kong Med J. 2018;24Suppl 2(1):45–7. 43. Patel JN, Klein DS, Sreekumar S, Liporace FA, Yoon RS. Outcomes in Multidisciplinary Team-based Approach in Geriatric Hip Fracture Care: A Systematic Review. J Am Acad Orthop Surg. 2020;28(3):128–33.
44. Sayeed Z, Anoushiravani A, El-Othmani M, Barinaga G, Sayeed Y, Cagle P Jr, et al. Implementation of a Hip Fracture Care Pathway Using Lean Six Sigma Methodology in a Level I Trauma Center. J Am Acad Orthop Surg. 2018; 26(24):881–93.

45. Ranhoff AH, Holvik K, Martinsen MI, Domaas K, Solheim LF. Older hip fracture patients: three groups with different needs. BMC Geriatr. 2010;10:65.

Publisher's Note

II

PLOS ONE

RESEARCH ARTICLE

Longitudinal trajectories of functional recovery after hip fracture

Shams Dakhil[1,2]*, Ingvild Saltvedt[3,4], Jūratė Šaltytė Benth[5,6], Pernille Thingstad[4], Leiv Otto Watne[1], Torgeir Bruun Wyller[1,2], Jorunn L. Helbostad[4], Frede Frihagen[2,7], Lars Gunnar Johnsen[4,8], Kristin Taraldsen[9]

1 Oslo Delirium Research Group, Department of Geriatric Medicine, Oslo University Hospital, Oslo, Norway, **2** Institute of Clinical Medicine, University of Oslo, Oslo, Norway, **3** Department of Geriatric Medicine, St. Olav University Hospital, Trondheim, Norway, **4** Department of Neuromedicine and Movement Science, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, **5** Institute of Clinical Medicine, Campus Ahus, University of Oslo, Oslo, Norway, **6** Health Services Research Unit, Akershus University Hospital, Lørenskog, Norway, **7** Department of Orthopaedic Surgery, Østfold Hospital Trust, Grålum, Norway, **8** Orthopedic Trauma Unit, Department of Orthopedic Surgery, St. Olav University Hospital, Trondheim, Norway, **9** Department of Rehabilitation Science and Health Technology, OsloMet, Oslo Metropolitan University, Oslo, Norway

* shamsdakhil@hotmail.com

OPEN ACCESS

Citation: Dakhil S, Saltvedt I, Benth JŠ, Thingstad P, Watne LO, Bruun Wyller T, et al. (2023) Longitudinal trajectories of functional recovery after hip fracture. PLoS ONE 18(3): e0283551. https://doi.org/10.1371/journal.pone.0283551

Editor: Robert Daniel Blank, Medical College of Wisconsin, UNITED STATES

Received: November 18, 2022

Accepted: March 1, 2023

Published: March 29, 2023

Data Availability Statement: Due to a statement by the Data Protection Officer at Oslo University Hospital, data can not be shared publicly because it is confidential (due to the consent given by the participants when included in the study). It is possible to extract information, upon request. Proposals should be directed to the Regional Ethics Committee for medical research in the South-East of Norway (contact: post@helseforsikring.etikkom.no).

Funding: The Oslo Orthogeriatric Trial was mainly funded by the Research Council of Norway. We

Abstract

Background

There is limited evidence regarding predictors of functional trajectories after hip fracture. We aimed to identify groups with different trajectories of functional recovery the first year after hip fracture, and to determine predictors for belonging to such groups.

Methods

This longitudinal study combined data from two large randomized controlled trials including patients with hip fracture. Participants were assessed at baseline, four and 12 months. We used the Nottingham Extended Activities of Daily Living (NEADL) as a measure of instrumental ADL (iADL) and Barthel Index for personal ADL (pADL). A growth mixture model was estimated to identify groups of patients following distinct trajectories of functioning. Baseline characteristics potentially predicting group-belonging were assessed by multiple nominal regression.

Results

Among 726 participants (mean age 83.0; 74.7% women), we identified four groups of patients following distinct ADL trajectories. None of the groups regained their pre-fracture ADL. For one of the groups identified in both ADL outcomes, a steep decline in function was shown the first four months after surgery, and none of the groups showed functional recovery between four and 12 months after surgery.

have also received funding from Norwegian National Health Association, the South-Eastern Norway Regional Health Authorities and the Medical Student Research Program in Norway. The Trondheim hip fracture study was funded by the Norwegian Research Council, the Central Norway Health Authority, the St. Olav Hospital Trust, the Department of Neuromedicine and Movement science, NTNU, the SINTEF and St. Olav Hospital Fund for Research and Innovation, and the Municipality of Trondheim. The sponsors had no role in the design and conduct of the study or methods, the collection, management, analysis, and interpretation of the data, or the preparation, review, and approval of the manuscript.

Competing interests: I. Saltvedt has performed Alzheimer a drug trial for Boehringer-Ingelheim 1346.0023. This trial was concluded in 2019. The remaining authors declare that they have no competing interests.

Conclusions

No groups regained their pre-fracture ADL. Some of the patients with relatively high pre-fracture function, had a steep ADL decline. For this group there is a potential for recovery, but more knowledge and research is needed in this group. These findings could be useful in uncovering groups of patients with different functioning after a hip fracture, and aid in discharge planning.

Introduction

With an ageing population, the number of hip fractures is expected to rise, even though the trends suggest a stabilization in age-adjusted rates [1, 2]. This condition in older adult patients is often associated with adverse outcomes, such as increased mortality and morbidity [3], increased dependency in Activities of Daily Living (ADL) [4–6], reduced mobility [7], and a negative effect on cognitive function [8, 9]. In addition to the individual negative outcomes, the increased dependency will also place a high demand on health care systems in the years to come. Thus, hip fractures constitute a major socioeconomic and public health burden worldwide [10, 11], and it is of value to investigate the best method for treating these patients.

Older adults suffering from a hip fracture are often characterized as frail, with multiple comorbidities and polypharmacy [12]. Many also have cognitive impairment or dementia [13], that increases the risk of falls and fractures [13], as well as for negative outcomes such as delirium [12], longer hospitalizations, a higher risk of death and nursing home admissions, and reduced functional recovery [14, 15]. Closely related is also a reduction in functional levels, both pre- and post-fracture [16]. Needless to say, this is a large and complex group of older adult patients, requiring many resources. Post-fracture recovery may therefore be impacted by many factors, and studying these factors to increase our knowledge about post-fracture recovery can aid in better treatment and discharge planning for this group of older adults.

A significant amount of hip fracture patients do not regain their pre-fracture function [6]. Having suffered a hip fracture is associated with more disability in personal Activities of Daily Living (pADL) and in instrumental ADL (iADL) [3], which could lead to an overall loss of confidence and independency [5]. Furthermore, a decline in ADL is subsequently associated with negative outcomes, such as reduced quality of life and increased nursing home admissions [17]. Thus, it is important to study ADL and the recovery of ADL after a hip fracture, to understand the mechanisms behind the decline. This knowledge could, in turn, lead to better and more personalized rehabilitation after a hip fracture.

Many older adults have declining functions already before the hip fracture occurs [18], which may be a contributing factor both to the hip fracture itself and the overall decline seen after the fracture. Due to the major impact ADL has on the lives of the older adults and the society, investigating ADL and its recovery in older adults suffering a hip fracture may therefore be of value.

Several studies aiming at identifying groups following distinct trajectories of function after hip fracture have been published in recent years [19–21]. One such study aimed to identify different groups following distinct trajectories of recovery, and found that frail hip fracture patients were more likely to belong to a trajectory with worse recovery compared to non-frail hip fracture patients, and that poor recovery was associated with dementia [22]. Identifying such groups and patient characteristics associated with these, may be useful in determining rehabilitation potential and targeting treatment to each patient. In turn, this may lead to a more individualized and cost-effective organization of hip fracture care and rehabilitation, and better function and health related quality of life among hip fracture patients [23]. By using a large and heterogeneous data material, we aimed to investigate whether there were homogenous groups of patients following different trajectories of recovery of physical function the first year after hospital discharge related to hip fracture, and to determine the most important predictors for belonging to such groups. We hypothesized that trajectories of functioning during the first year after the fracture vary depending on patient characteristics before the fracture.

Materials and methods

Design

This is a longitudinal study based on data from two randomized clinical trials conducted in Norway [12, 23]; The Oslo Orthogeriatric Trial (n = 329, inclusion between 2009–2012) and the Trondheim Hip Fracture Trial (n = 397, inclusion between 2008–2010). Both studies aimed to evaluate the effect of orthogeriatric care and were planned with similar design for future pooling of the data [24, 25]. The population did, however, slightly differ between the two studies. The Trondheim study only included home-dwelling patients, 70 years or older, who were able to walk at least 10 meters before the hip fracture. The Oslo study included all low-energy hip fracture patients at all ages, independent of place of residence. Both studies excluded patients who were moribund at admission or had suffered a hip fracture due to high-energy trauma. In both studies, participants received comprehensive geriatric care (CGC) in a geriatric ward or usual care in an orthopedic ward (OC) during the hospital stay, full details on the intervention are described in their study protocols [24, 25]. Patients were followed one year after surgery, with assessments at baseline, four and 12 months. The Oslo Orthogeriatric Trial found no effect of the intervention on cognitive function (primary endpoint), however there was an effect on mobility four months after surgery for home-dwelling patients (preplanned subgroup analysis) [12]. For the Trondheim Hip Fracture Trial, better mobility and iADL was found for the intervention group four months after surgery, and the intervention was beneficial for most secondary outcomes, as well as being cost effective up to one year after surgery [23].

Sample and setting

In the present study, we used the pooled data from the two studies, yielding a database with 726 participants.

Measurements

Descriptive measures. Baseline characteristics included randomization (CGC vs OC), sex (male/female), age (years), type of fracture (extracapsular vs intracapsular) and preoperative waiting time (hours). The preoperative physical health was assessed by the American Society of Anesthesiologists (ASA) score, a classification system using four categories of physical status, which were dichotomized (1 or 2 vs 3 or 4) in this study [26]. In addition, cognitive function at baseline was assessed using the Clinical Dementia Rating Scale (CDR) [27], which is a global rating scale, where current functioning in six domains is rated based on changes in cognitive function from previous usual levels. By adding the scores for each item, the CDR sum of boxes, ranging from 0 to 18, is achieved; a low sum score indicating little or no cognitive impairment [28].

Outcomes. We included two functional outcomes; instrumental and personal ADL. We used the Nottingham Extended ADL Scale (NEADL) to measure **iADL** [29]. NEADL is a 22 items scale with scores ranging from 0 to 66, where a higher score indicates better iADL [29]. We used the Barthel ADL Index (BADL) to measure **pADL** [30]. BADL is a 10-item scale with scores ranging from 0 to 20, where a higher BADL score suggests higher independency in undertaking pADL [30]. Both outcomes were collected at baseline, four and 12 months post-operatively, where the baseline value represents patients' pre-fracture function and obtained by proxy interview asking for function 14 days before the fracture, and the value at both follow-ups were obtained by proxy interview and face-to-face evaluations.

Statistical methods

Participant characteristics were described as means and standard deviations (SDs) or frequencies and percentages.

Growth mixture models [31] were used to identify possible homogeneous groups of participants following distinct trajectories in NEADL and BADL. This approach is suitable for identifying groups of patients based on their individual profiles by using several statistical criteria. To determine the number of groups that best cover the heterogeneity in participants' profiles, Bayes Information Criterion, where a smaller value means a better model, was applied. In addition, an average within-group probability of at least 0.80, reasonable group sizes, and non-overlapping 95% confidence intervals (CIs) of the group trajectories were required. Patients completing at least baseline test were included in the analyses.

Patient characteristics within different groups were presented as frequencies and percentages or means and SDs. Multiple nominal regression models were used to assess which baseline characteristics (sex, age, type of fracture, preoperative waiting time, ASA score and CDR) were associated with group-belonging. In all models, the largest group was used as reference. As the data were collected from different hospitals, a cluster effect might be present. The cluster effect was assessed by intra-class correlation coefficient. If present, it was adjusted for by including random effects for hospital into the nominal regression model. The variable for care models, CGC or OC, was treated as control variable in our analysis. The analysis included patients with no missing values on considered characteristics. The results were presented as odds ratios (ORs) with corresponding 95% CIs and p-values.

All tests were two-sided and results with p-values < 0.05 were considered statistically significant. The analyses were performed by using SPSS v26, SAS v9.4, and STATA v14.

Ethical considerations

The Oslo Orthogeriatric Trial was registered with ClinicalTrials.gov (NCT01009268), and approved by the Regional Committee for Ethics in Medical Research in South East of Norway (REK 2009/450). The Trondheim Hip Fracture Trial was registered with ClinicalTrials.gov (NCT00667914), and approved by the Regional Committee for Ethics in Medical Research in Central Norway (REK4.2008.335). The Regional Committee for Ethics in Medical Research in South East of Norway and the Data Protection Officer at both hospitals approved merging of data from the two separate trials.

Both studies were conducted in accordance with the Declaration of Helsinki. The patients or a proxy gave informed written consent to be included in the study before participation in both trials.

Results

We included 726 participants (mean age 83.0 (7.7) years, 74.7% women, 60.7% intracapsular fracture). Out of the 726 participants, 361 were randomized to CGC and 365 were randomized to OC, with no between-group differences in baseline characteristics [32]. Participants' baseline characteristics are presented in Table 1.

Four different groups of patients following distinct trajectories for each of the two ADL variables were identified, see Fig 1. For iADL, the two groups, *'Very good function'* (n = 175, 24.8%) and *'Good function'* (n = 155, 22.0%) comprised roughly half of the patients. The *'Poor function'* (n = 143, 20.3%) group showed relatively high baseline iADL (mean 31.5), but declined steeply the first four months after the fracture (mean 15.7 at last assessment). The *'Very poor function'* (n = 232, 32.9%) group showed low pre-fracture iADL (mean 11.8) and were relatively stable. For pADL, two groups maintained relatively good function, the *'Very good function'* (n = 187, 26.3%, mean 19.9 at baseline) and *'Good function'* (n = 331, 46.6%, mean values 17.6, 16.5 and 16.4 at each assessment, respectively) groups, whereas two groups had a steep decline in pADL the first four months after hip fracture; *'Poor function'* (n = 154, 21.7%, mean values 13.4, 9.5 and 8.6 at each assessment, respectively) and *'Very poor function'* (n = 38, 5.4%, mean values 6.1, 3.6 and 3.0 at each assessment, respectively). Average group probabilities were all above 0.8 and 95% CIs non-overlapping, implying homogeneous groups. For both iADL and pADL, all trajectories were non-linear and declined significantly over 12 months (all p's <0.001 and <0.01, respectively). See Table 2 for details.

Table 1. Baseline characteristics.

Subjects, n	**726**
Age, mean (SD)	83.0 (7.7)
Sex, female (%)	542 (74.7)
Type of fracture, intracapsular (%)	441 (60.7)
Living in a nursing home at admission[a] (%)	102 (14.0)
NEADL[b] (0–66), mean (SD)	37.3 (20.2)
BADL[c] (0–20)	17.3 (3.6)
CDR sum of boxes[d] (0–18), mean (SD)	4.2 (5.4)
Preop. waiting time[e,f] (hours), mean (SD)	29.9 (23.3)
ASAg score 3 or more (%)	415 (59.2)
Patients included from Trondheim (%)	397 (54.7)
Randomization to intervention, CGC (%)	361 (49.7)

SD Standard Deviation. *NEADL* Nottingham Extended Activities of Daily Living. *BADL* Barthel Index for Activities of Daily Living. *CDR* Clinical Dementia rating Scale. *Preop. waiting time* Preoperative waiting time. *ASA* American Society of Anaesthesiologists Physical Status Classification system. *CGC* Comprehensive Geriatric Care.

[a] Patients admitted from a nursing home was excluded in Trondheim.

[b] Baseline NEADL was based on pre-fracture function, and was obtained by proxy-interview. It was missing from 21 patients.

[c] Baseline BADL was based on pre-fracture function, and was obtained by proxy-interview. It was missing from 16 patients.

[d] Baseline CDR sum of boxes was obtained during hospital and was, in part based on proxy-interview. It was missing in 52 patients.

[e] Outlier, 235h.

[f] Information about preoperative waiting time was missing in 9 patients.

[g] ASA score was missing in 25 patients.

https://doi.org/10.1371/journal.pone.0283551.t001

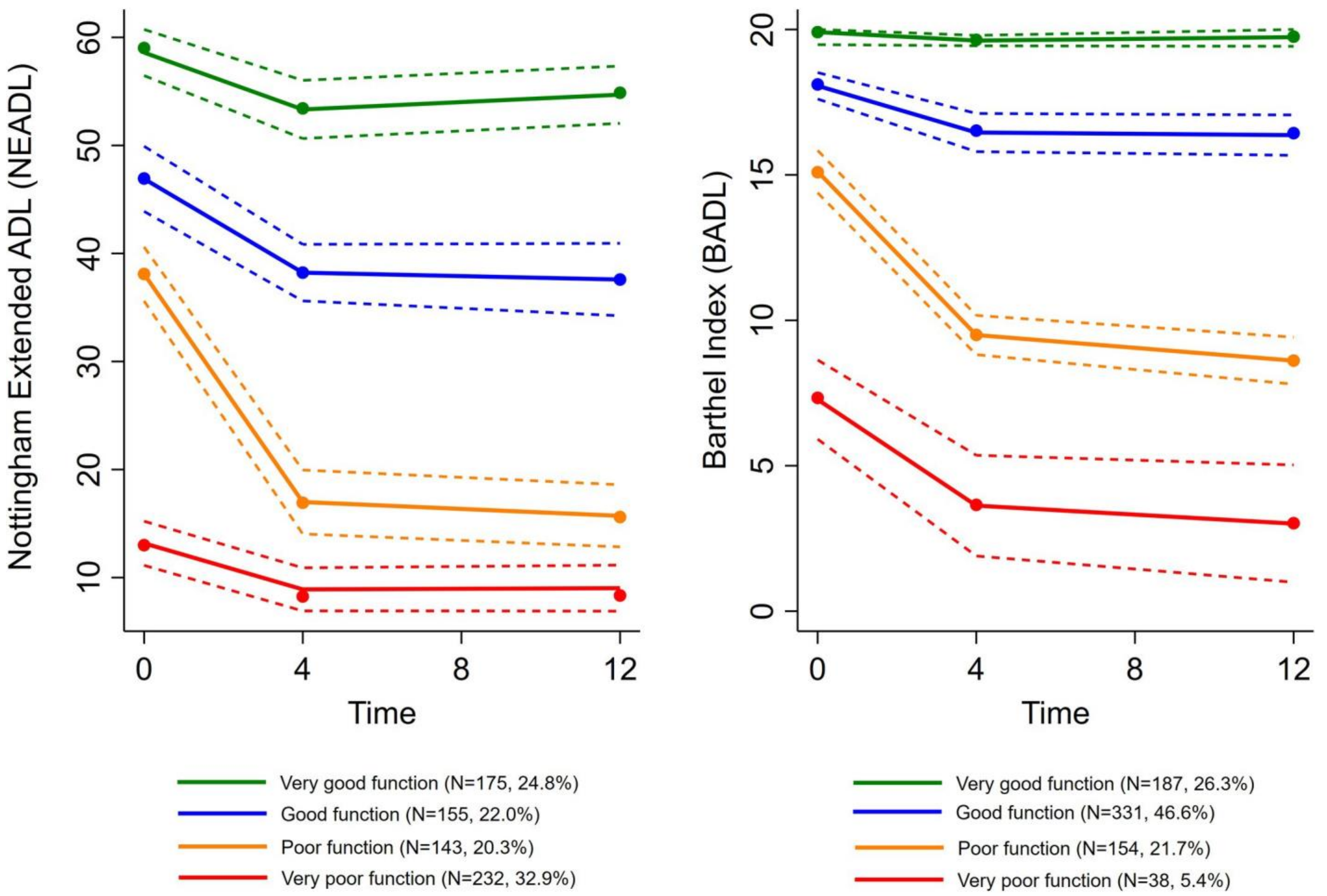

Fig 1. Growth mixture models for instrumental activities of Daily Living (NEADL) and personal activities of Daily Living (BADL) with corresponding confidence intervals.

https://doi.org/10.1371/journal.pone.0283551.g001

Table 2. Results of the growth mixture model.

	Mean (SD) at baseline	Linear component		Quadratic component	
		Regression coefficient (SE)	p-value	Regression coefficient (SE)	p-value
Instrumental Activities of Daily Living (NEADL)					
Very poor function (G1) (n = 232, 32.9%)	13.01 (7.9)	-1.61 (0.35)	**<0.001**	0.10 (0.03)	**<0.001**
Poor function (G2) (n = 143, 20.3%)	38.3 (9.4)	-7.00 (0.60)	**<0.001**	0.43 (0.04)	**<0.001**
Good function (G3) (n = 155, 22.0%)	47.4 (9.7)	-2.88 (0.44)	**<0.001**	0.18 (0.03)	**<0.001**
Very good function (G4) (n = 175, 24.8%)	59.7 (5.6)	-2.11 (0.38)	**<0.001**	0.14 (0.03)	**<0.001**
Personal Activities of Daily Living (BADL)					
Very poor function (G1) (n = 38, 5.4%)	7.0 (3.6)	-1.23 (0.29)	**<0.001**	0.07 (0.02)	**0.002**
Poor function (G2) (n = 154, 21.7%)	14.7 (2.7)	-1.85 (0.14)	**<0.001**	0.11 (0.01)	**<0.001**
Good function (G3) (N = 331, 46.6%)	18.2 (1.7)	-0.66 (0.09)	**<0.001**	0.04 (0.01)	**<0.001**
Very good function (G4) (n = 187, 26.3%)	20.0 (0.2)	-0.69 (0.22)	**0.002**	0.05 (0.02)	**0.002**

Growth mixture models for instrumental Activities of Daily and personal Activities of Daily Living. *SD* Standard deviation. *SE* Standard error. *NEADL* Nottingham Extended Activities of Daily Living. *BADL* Barthel Index for Activities of Daily Living.

https://doi.org/10.1371/journal.pone.0283551.t002

Table 3. Characteristics of patients according to trajectories.

Variable	Subjects *n* (%)	Age *years* (SD)	Female Sex *n* (%)	Nursing home *n* (%)	ASA score 1+2 *n* (%)	ASA score 3+ *n* (%)	Type of fracture, Intracapsular *n* (%)
Overall	726 (100)						
Instrumental Activities of Daily Living (NEADL)							
Very poor function (G1)	232 (32.9)	85.2 (6.6)	165 (71.1)	97 (41.8)	57 (25.9)	163 (74.1)	141 (60.8)
Poor function (G2)	143 (20.3)	85.1 (7.0)	107 (74.8)	2 (1.4)	49 (35.3)	90 (64.7)	76 (53.1)
Good function (G3)	155 (22.0)	82.2 (7.4)	121 (78.1)	1 (0.6)	71 (46.4)	82 (53.6)	91 (58.7)
Very good function (G4)	175 (24.8)	79.0 (8.3)	131 (74.9)	0	100 (59.9)	67 (40.1)	119 (68.0)
Personal Activities of Daily Living (BADL)							
Very poor function (G1)	38 (5.4)	82.9 (8.1)	28 (73.7)	28 (73.7)	6 (17.6)	28 (82.4)	27 (71.1)
Poor function (G2)	154 (21.7)	85.7 (6.0)	108 (70.1)	52 (33.8)	31 (20.5)	120 (79.5)	81 (52.6)
Good function (G3)	331 (46.6)	83.7 (7.4)	267 (80.7)	20 (6.0)	137 (42.9)	182 (57.1)	195 (58.9)
Very good function (G4)	187 (26.3)	79.6 (8.2)	126 (67.4)	0	106 (58.9)	74 (41.1)	127 (67.9)

Characteristics of patients according to trajectories.

SD Standard deviation. *ASA score* American Society of Anaesthesiologists Physical Status Classification system. *iADL* Instrumental Activities of Daily Living. *NEADL* Nottingham Extended Activities of Daily Living. *pADL* Personal Activities of Daily Living. *BADL* Barthel Index for Activities of Daily Living

https://doi.org/10.1371/journal.pone.0283551.t003

Participants' characteristics stratified by the trajectory groups are presented in Table 3. For both iADL and pADL, mean age was lowest and no participant was admitted from a nursing home in the *'Very good function'* groups. Furthermore, for both the *'Very good function'* and the *'Good function'* groups for both iADL and pADL, lower ASA score and an intracapsular fracture were more common.

In the *'Very poor function'* groups for both iADL and pADL, being admitted from a nursing home, a high ASA score and an intracapsular fracture were more common.

For both the *'Poor function'* groups, higher age and higher ASA score were more common.

Table 4 presents the results from the multiple nominal regression models. For iADL, higher age was associated with lower odds of being in the *´Good function'* (OR 0.94, p = 0.003) and *´Very good function´* (OR 0.89, p<0.001) groups, and higher CDR sum was associated with higher odds of being in the *´Very poor function´* group (all p's<0.001). Furthermore, ASA score of 1 or 2 compared to a higher ASA score, was associated with higher odds of belonging to the *´Good function´* (OR 1.84, p = 0.048) and *'Very good function´* (OR 3.28, p<0.001) groups. For pADL, men compared to women had higher odds of belonging to the *'Very good function'* group (OR 3.29, p<0.001). Increasing age was associated with lower odds of belonging to the *'Very poor function'* (OR 0.93, p = 0.028) and *'Very good function'* (OR 0.94, p<0.001) groups, and increasing CDR sum was associated with higher odds of belonging to the *'Very poor function'* (OR 1.57, p<0.001) group. Moreover, lower ASA score was associated with higher odds of belonging to the *'Very good function'* group (OR 2.17, p = 0.001), and having suffered an extracapsular hip fracture were associated with lower odds of belonging to the *'Very good function'* (OR 0.49, p = 0.002) group.

For iADL and pADL, 316 participants (44.6%) belonged to the same trajectory group in both outcomes (for example 38 participants belong to the *'Very poor function'* group for iADL and the corresponding *'Very poor function'* group for pADL). The cross-table presenting agreement between group-belonging (see Table 5) was followed by a kappa of 0.46 (CI: 0.42–0.50), which is consistent with moderate agreement across the groups.

Table 4. Results of the multiple nominal regression model.

Covariate	Multiple model for iADL (NEADL), N = 641		Multiple model for pADL (BADL), N = 645	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Randomization				
Orthopedic (OC)	1		1	
Geriatric (CGC)				
Very poor function (G1)	1		1.27 (0.50; 3.27)	0.615
Poor function (G2)	0.62 (0.37; 1.05)	0.077	0.83 (0.51; 1.35)	0.446
Good function (G3)	0.90 (0.51; 1.59)	0.713	1	
Very good function (G4)	1.12 (0.60; 2.09)	0.729	0.89 (0.58; 1.37)	0.605
Sex				
Male				
Very poor function (G1)	1		0.63 (0.21; 1.92)	0.418
Poor function (G2)	0.94 (0.51; 1.73)	0.846	1.31 (0.74; 2.31)	0.354
Good function (G3)	0.87 (0.44; 1.70)	0.681	1	
Very good function (G4)	1.15 (0.55; 2.39)	0.718	3.29 (1.97; 5.52)	<0.001
Female	1		1	
Age				
Very poor function (G1)	1		0.93 (0.86; 0.99)	0.028
Poor function (G2)	1.00 (0.96; 1.04)	0.877	1.03 (0.99; 1.07)	0.136
Good function (G3)	0.94 (0.90; 0.98)	0.003	1	
Very good function (G4)	0.89 (0.85; 0.94)	<0.001	0.94 (0.92; 0.97)	<0.001
Type of fracture				
Extracapsular				
Very poor function (G1)	1		0.73 (0.27; 1.98)	0.539
Poor function (G2)	1.33 (0.78; 2.26)	0.295	1.51 (0.93; 2.47)	0.100
Good function (G3)	0.97 (0.54; 1.72)	0.905	1	
Very good function (G4)	0.59 (0.31; 1.12)	0.107	0.49 (0.31; 0.77)	0.002
Intracapsular	1		1	
Preop. waiting time				
Very poor function (G1)	1		1.00 (0.99; 1.02)	0.641
Poor function (G2)	1.00 (0.99; 1.01)	0.913	1.00 (0.99; 1.01)	0.997
Good function (G3)	1.01 (0.99;	0.236	1	
Very good function (G4)	1.02)	0.547	1.00 (0.99; 1.01)	0.727
ASA score	1.01 (1.00;			
1 or 2	1.02)			
Very poor function (G1)			0.27 (0.08; 0.90)	0.034
	1			
Poor function (G2)	1.24 (0.71; 2.18)	0.457	0.42 (0.24; 0.73)	0.002
Good function (G3)	1.84 (1.01; 3.35)	0.048	1	
Very good function (G4)	3.28 (1.70; 6.32)	<0.001	2.17 (1.40; 3.38)	0.001
3 or more	1		1	
CDR sum of boxes				
Very poor function (G1)	1		1.57 (1.39; 1.77)	<0.001
Poor function (G2)	0.76 (0.71; 0.81)	<0.001	1.29 (1.23; 1.39)	<0.001
Good function (G3)	0.61 (0.55; 0.67)	<0.001	1	

(*Continued*)

Table 4. (Continued)

Covariate	Multiple model for iADL (NEADL), N = 641		Multiple model for pADL (BADL), N = 645	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Very good function (G4)	0.35 (0.28; 0.44)	<0.001	0.66 (0.58; 0.75)	<0.001

Multiple nominal regression model with CGC or OC as control variable. The analysis included patients with no missing values on considered characteristics. OR = 1 indicates odds ratios for the reference (largest) group.

iADL Instrumental Activities of Daily Living. *NEADL* Nottingham Extended Activities of Daily Living. *pADL* Personal Activities of Daily Living. *BADL* Barthel Index for Activities of Daily Living. *OR* Odds ratio. *CI* Confidence interval. *OC* Orthopedic care. *CGC* Comprehensive Geriatric Care. *Preop. waiting time* Preoperative waiting time. *ASA score* American Society of Anaesthesiologists Physical Status Classification system. *CDR sum of boxes* Clinical Dementia rating Scale sum of boxes.

https://doi.org/10.1371/journal.pone.0283551.t004

Discussion

In this longitudinal cohort of 726 older adults we studied functional decline one year after hip fracture. The statistical analyses identified four groups following distinct trajectories for both iADL and pADL. For both iADL and pADL, most trajectories did not regain their pre-fracture ADL levels. Overall, younger age, an ASA score of 1 or 2, and lower CDR score were all associated with belonging to groups with higher ADL and better trajectories. We also identified a group of patients for both iADL and pADL with relatively good pre-fracture function, but with a steep decline in ADL function the first four months after the fracture. This decline remained one year after fracture.

As a difference higher than 2.4 points in NEADL is considered clinically relevant [33], and a one-point difference in BADL distinguishes being independent or dependent in certain items of pADL (such as for walking, feeding and toilet use), we believe all groups show a clinically relevant decline in ADL the first year after a hip fracture. Due to the higher complexity of iADL tasks, it is not unusual that patients first experience deterioration iADL and then in pADL, which might explain the kappa agreement of 46% in our analysis.

For all iADL and pADL trajectories, the functional decline was steepest the first four months after the fracture, with no functional recovery between four and 12 months. Whether it is because the participants had reached their maximum rehabilitation potential, or because the rehabilitation offered concluded prematurely, remains to be explored [34]. Nevertheless, these trajectories may represent different groups of patients with different rehabilitation needs, and a need for more personalized rehabilitation, especially in early phases when discharge are planned and during the first months after the hip fracture.

Table 5. Crosstabulation between iADL and pADL groups.

Groups	Personal Activities of Daily Living (BADL) groups					Total
		G1	G2	G3	G4	
Instrumental Activities of Daily Living (NEADL) groups	G1, count (% of total)	38 (5.4)	120 (17.0)	74 (10.5)	0 (0)	232 (33.0)
	G2, count (% of total)	0 (0)	33 (4.7)	101 (14.3)	9 (1.3)	143 (20.3)
	G3, count (% of total)	0 (0)	0 (0)	111 (15.8)	44 (6.3)	155 (22.0)
	G4, count (% of total)	0 (0)	0 (0)	40 (5.7)	134 (19.0)	174 (24.7)
Total, count (% of total)		38 (5.4)	153 (21.7)	326 (46.3)	187 (26.6)	704 (100)

Crosstabulation presenting agreement between group-belonging, which is consistent with moderate agreement across groups (kappa 0.46).

iADL Instrumental Activities of Daily Living. *pADL* Personal Activities of Daily Living. *NEADL* Nottingham Extended Activities of Daily Living. *BADL* Barthel Index for Activities of Daily Living.

G1 Very poor function. *G2* Poor function. *G3* Good function. *G4* Very good function.

https://doi.org/10.1371/journal.pone.0283551.t005

The large and steep decline in ADL in the group of patients following the *'Poor function'* trajectory of both iADL and pADL may represent a potential for improved acute care and rehabilitation, especially because of the relatively high pre-fracture ADL status of these participants. The group of patients following these trajectories experienced a gross decline in ADL the first four months after a hip fracture, which persisted over the following year. These groups were characterized by older patients with higher ASA scores.

ASA score is a measure of preoperative function, and a reflection of the patients' preoperative clinical status, comorbidities and physical fitness. Higher ASA score is associated with higher mortality [35], longer hospitalization [36] and more hospital readmissions [37], and is an important prognostic factor. Identifying patients belonging to these groups might be clinically relevant, since correcting for comorbidities and optimizing treatment, as well as intensified rehabilitation for such patients could be of importance to avoid the large decline in ADL. Furthermore, the groups of patients following the *'Poor function'* trajectory for both iADL and pADL were mostly home-dwellers (1.4% and 33.8% admitted from a nursing home, respectively), see Table 3. Theoretically, these patients should be less frail, but when admitted to the hospital after a hip fracture, they have high ASA scores reflecting frailty or acute disease before or during the hip fracture. The high ASA score in this group could be a contributing factor to their steep decline in ADL–either by reflecting a disease that contributes to the fall and fracture, or by reflecting an innate frailty that subsequently result in worse ADL recovery. The mechanisms behind this are not yet known. Future research on this group of patients is important to increase the evidence regarding adequate acute treatment and rehabilitation that can be offered in this group.

In our sample, over half of the older adults with hip fracture were in the two lower groups of iADL, with approximately 30% in the lowest group in which iADL was already poor before the fracture. These groups stand out, probably illustrating that for some older adults their already low pre-fracture iADL could be a contributing factor to the fall, subsequent hip fracture and overall decline in function postoperatively. This is in alignment with literature finding that pre-fracture function is an important factor for post-fracture functional recovery [38–42].

The major strengths of this study are the relatively high number of participants that are followed for one year after hip fracture, and the comprehensive and systematic collection of clinically relevant outcomes. The study participants were representative of older adults with hip fracture, with the Oslo study including hip fracture patients regardless of living conditions prior to the fracture and the Trondheim study including home-dwelling hip fracture patients above 70 years. Our results indicate that growth mixture modelling can be a useful tool in identifying homogeneous groups of patients following distinct trajectories of ADL after hip fracture. The limitations of this study include that some outcomes collected at baseline by proxy interview could be biased by the knowledge of the recent hip fracture. We also acknowledge that the Trondheim cohort did not include nursing home residents, thus explaining the lower proportion of nursing home residents in our material.

In summary, we identified four groups of older adults with hip fracture that followed distinct trajectories of iADL and pADL the first year after the fracture. Younger age, an ASA score of 1 or 2, and better cognitive function at baseline were all associated with belonging to a group with better ADL. For all groups there was no functional recovery between four and 12 months after the fracture, and no group showed recovery to pre-fracture functional levels. We also identified a group with relatively high ADL before the fracture, followed by a steep decline afterwards. This group is of particular clinical interest since it may impose a significant potential for rehabilitation. Future studies should explore how to target treatment for groups of older adults with steep declines in functioning after a hip fracture. Our findings could potentially be useful for the quality, efficacy and type of care hip fracture patients should be offered, promoting construction of clinical profiles to aid in more individualized rehabilitation and discharge planning.

Acknowledgments

The authors would like to thank the patients and staff at the Orthopedic Department and the Geriatric Department at Oslo University Hospital and St. Olavs Hospital, Trondheim University hospital. They also thank research nurses Elisabeth Fragaat, Tone Fredriksen, Camilla Marie Andersen, Julie Ask Ottesen and Linda Feldt for assisting in data collection. Further we want to thank members of the study group in Trondheim especially Anders Prestmo and Sarah Lamb for their valid contribution in planning and performing the Trondheim part of the study.

Author Contributions

Conceptualization: Shams Dakhil, Ingvild Saltvedt, Pernille Thingstad, Leiv Otto Watne, Torgeir Bruun Wyller, Jorunn L. Helbostad, Frede Frihagen, Lars Gunnar Johnsen, Kristin Taraldsen.

Data curation: Shams Dakhil, Ingvild Saltvedt, Pernille Thingstad, Leiv Otto Watne, Torgeir Bruun Wyller, Jorunn L. Helbostad, Frede Frihagen, Lars Gunnar Johnsen, Kristin Taraldsen.

Formal analysis: Jūratė Šaltytė Benth, Leiv Otto Watne.

Investigation: Jūratė Šaltytė Benth.

Methodology: Shams Dakhil, Ingvild Saltvedt, Jūratė Šaltytė Benth, Leiv Otto Watne, Torgeir Bruun Wyller, Kristin Taraldsen.

Supervision: Ingvild Saltvedt, Leiv Otto Watne, Torgeir Bruun Wyller, Kristin Taraldsen.

Visualization: Shams Dakhil.

Writing – original draft: Shams Dakhil, Jūratė Šaltytė Benth, Leiv Otto Watne, Kristin Taraldsen.

Writing – review & editing: Shams Dakhil, Ingvild Saltvedt, Jūratė Šaltytė Benth, Pernille Thingstad, Leiv Otto Watne, Torgeir Bruun Wyller, Jorunn L. Helbostad, Frede Frihagen, Lars Gunnar Johnsen, Kristin Taraldsen.

References

1. Cooper C, Cole ZA, Holroyd CR, Earl SC, Harvey NC, Dennison EM, et al. Secular trends in the inci- dence of hip and other osteoporotic fractures. Osteoporosis international: a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2011; 22(5):1277–88. https://doi.org/10.1007/s00198-011-1601-6 PMID: 21461721
2. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. Injury. 2018; 49(8):1458–60. https://doi.org/10.1016/j.injury.2018.04.015 PMID: 29699731
3. Bentler SE, Liu L, Obrizan M, Cook EA, Wright KB, Geweke JF, et al. The aftermath of hip fracture: dis- charge placement, functional status change, and mortality. Am J Epidemiol. 2009; 170(10):1290–9. https://doi.org/10.1093/aje/kwp266 PMID: 19808632
4. Rosell PA, Parker MJ. Functional outcome after hip fracture. A 1-year prospective outcome study of 275 patients. Injury. 2003; 34(7):529–32. https://doi.org/10.1016/s0020-1383(02)00414-x PMID: 12832181

5. Pasco JA, Sanders KM, Hoekstra FM, Henry MJ, Nicholson GC, Kotowicz MA. The human cost of frac- ture. Osteoporosis international: a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2005; 16 (12):2046–52. https://doi.org/10.1007/s00198-005-1997-y PMID: 16228106

6. Magaziner J, Hawkes W, Hebel JR, Zimmerman SI, Fox KM, Dolan M, et al. Recovery from hip fracture in eight areas of function. The journals of gerontology Series A, Biological sciences and medical sci- ences. 2000; 55(9):M498–507. https://doi.org/10.1093/gerona/55.9.m498 PMID: 10995047

7. Resnick B, Galik E, Boltz M, Hawkes W, Shardell M, Orwig D, et al. Physical activity in the post-hip-frac- ture period. J Aging Phys Act. 2011; 19(4):373–87. https://doi.org/10.1123/japa.19.4.373 PMID: 21911877

8. Krogseth M, Wyller TB, Engedal K, Juliebø V. Delirium is an important predictor of incident dementia among elderly hip fracture patients. Dementia and geriatric cognitive disorders. 2011; 31(1):63–70. https://doi.org/10.1159/000322591 PMID: 21212674

9. Krogseth M, Watne LO, Juliebo V, Skovlund E, Engedal K, Frihagen F, et al. Delirium is a risk factor for further cognitive decline in cognitively impaired hip fracture patients. Archives of gerontology and geriat- rics. 2016; 64:38–44. https://doi.org/10.1016/j.archger.2015.12.004 PMID: 26952375

10. Cheng SY, Levy AR, Lefaivre KA, Guy P, Kuramoto L, Sobolev B. Geographic trends in incidence of hip fractures: a comprehensive literature review. Osteoporosis international: a journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA. 2011; 22(10):2575–86. https://doi.org/10.1007/s00198-011-1596-z PMID: 21484361

11. Hernlund E, Svedbom A, Ivergard M, Compston J, Cooper C, Stenmark J, et al. Osteoporosis in the European Union: medical management, epidemiology and economic burden. A report prepared in col- laboration with the International Osteoporosis Foundation (IOF) and the European Federation of Phar- maceutical Industry Associations (EFPIA). Archives of osteoporosis. 2013; 8:136. https://doi.org/10. 1007/s11657-013-0136-1 PMID: 24113837

12. Watne LO, Torbergsen AC, Conroy S, Engedal K, Frihagen F, Hjorthaug GA, et al. The effect of a pre- and postoperative orthogeriatric service on cognitive function in patients with hip fracture: randomized controlled trial (Oslo Orthogeriatric Trial). BMC medicine. 2014; 12:63. https://doi.org/10.1186/1741- 7015-12-63 PMID: 24735588

13. Vun JSH, Ahmadi M, Panteli M, Pountos I, Giannoudis PV. Dementia and fragility fractures: Issues and solutions. Injury. 2017; 48 Suppl 7:S10–s6. https://doi.org/10.1016/j.injury.2017.08.031 PMID: 28851522

14. Young Y, Xiong K, Pruzek RM. Longitudinal functional recovery after postacute rehabilitation in older hip fracture patients: the role of cognitive impairment and implications for long-term care. Journal of the American Medical Directors Association. 2011; 12(6):431–8. https://doi.org/10.1016/j.jamda.2010.08. 005 PMID: 21450204

15. Jones CA, Jhangri GS, Feeny DH, Beaupre LA. Cognitive Status at Hospital Admission: Postoperative Trajectory of Functional Recovery for Hip Fracture. The journals of gerontology Series A, Biological sci- ences and medical sciences. 2017; 72(1):61–7. https://doi.org/10.1093/gerona/glv138 PMID: 26297654

16. Kristensen MT, Foss NB, Ekdahl C, Kehlet H. Prefracture functional level evaluated by the New Mobility Score predicts in-hospital outcome after hip fracture surgery. Acta orthopaedica. 2010; 81(3):296–302. https://doi.org/10.3109/17453674.2010.487240 PMID: 20450426

17. Alexiou KI, Roushias A, Varitimidis SE, Malizos KN. Quality of life and psychological consequences in elderly patients after a hip fracture: a review. Clinical interventions in aging. 2018; 13:143–50. https:// doi.org/10.2147/CIA.S150067 PMID: 29416322

18. Ravensbergen WM, Blom JW, Kingston A, Robinson L, Kerse N, Teh RO, et al. Declining daily function- ing as a prelude to a hip fracture in older persons-an individual patient data meta-analysis. Age and age- ing. 2022; 51(1). https://doi.org/10.1093/ageing/afab253 PMID: 35077559

19. Chen LH, Liang J, Chen MC, Wu CC, Cheng HS, Wang HH, et al. The relationship between preopera- tive American Society of Anesthesiologists Physical Status Classification scores and functional recov- ery following hip-fracture surgery. BMC musculoskeletal disorders. 2017; 18(1):410. https://doi.org/10. 1186/s12891-017-1768-x PMID: 29017476

20. Beishuizen SJE, van Munster BC, de Jonghe A, Abu-Hanna A, Buurman BM, de Rooij SE. Distinct Cog- nitive Trajectories in the First Year After Hip Fracture. Journal of the American Geriatrics Society. 2017; 65(5):1034–42. https://doi.org/10.1111/jgs.14754 PMID: 28152178

21. Savino E, Martini E, Lauretani F, Pioli G, Zagatti AM, Frondini C, et al. Handgrip strength predicts per- sistent walking recovery after hip fracture surgery. Am J Med. 2013; 126(12):1068–75.e1. https://doi. org/10.1016/j.amjmed.2013.04.017 PMID: 24054175

22. de Munter L, van de Ree CLP, van der Jagt OP, Gosens T, Maas H, de Jongh MAC. Trajectories and prognostic factors for recovery after hip fracture: a longitudinal cohort study. International orthopaedics. 2022. https://doi.org/10.1007/s00264-022-05561-4 PMID: 36066616

23. Prestmo A, Hagen G, Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, et al. Comprehensive geriat- ric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet (London, England). 2015; 385(9978):1623–33. https://doi.org/10.1016/S0140-6736(14)62409-0 PMID: 25662415

24. Wyller TB, Watne LO, Torbergsen A, Engedal K, Frihagen F, Juliebo V, et al. The effect of a pre- and post-operative orthogeriatric service on cognitive function in patients with hip fracture. The protocol of the Oslo Orthogeriatrics Trial. BMC geriatrics. 2012; 12:36. https://doi.org/10.1186/1471-2318-12-36 PMID: 22817102

25. Sletvold O, Helbostad JL, Thingstad P, Taraldsen K, Prestmo A, Lamb SE, et al. Effect of in-hospital comprehensive geriatric assessment (CGA) in older people with hip fracture. The protocol of the Trond- heim Hip Fracture trial. BMC geriatrics. 2011; 11:18. https://doi.org/10.1186/1471-2318-11-18 PMID: 21510886

26. Wolters U, Wolf T, Stu¨tzer H, Schro¨der T. ASA classification and perioperative variables as predictors of postoperative outcome. Br J Anaesth. 1996; 77(2):217–22. https://doi.org/10.1093/bja/77.2.217 PMID: 8881629

27. Hughes CP, Berg L, Danziger WL, Coben LA, Martin RL. A new clinical scale for the staging of demen- tia. The British journal of psychiatry: the journal of mental science. 1982; 140:566–72. https://doi.org/10.1192/bjp.140.6.566 PMID: 7104545

28. O'Bryant SE, Waring SC, Cullum CM, Hall J, Lacritz L, Massman PJ, et al. Staging dementia using Clin- ical Dementia Rating Scale Sum of Boxes scores: a Texas Alzheimer's research consortium study. Archives of neurology. 2008; 65(8):1091–5. https://doi.org/10.1001/archneur.65.8.1091 PMID: 18695059

29. Gladman JR, Lincoln NB, Adams SA. Use of the extended ADL scale with stroke patients. Age and age- ing. 1993; 22(6):419–24. https://doi.org/10.1093/ageing/22.6.419 PMID: 8310887

30. Wade DT. Measurement in neurological rehabilitation. Current opinion in neurology and neurosurgery. 1992; 5(5):682–6. PMID: 1392142

31. Nagin D. Group-Based Modeling of Development: Harvard University Press; 2009.

32. Dakhil S, Thingstad P, Frihagen F, Johnsen LG, Lydersen S, Skovlund E, et al. Orthogeriatrics prevents functional decline in hip fracture patients: report from two randomized controlled trials. BMC geriatrics. 2021; 21(1):208. https://doi.org/10.1186/s12877-021-02152-7 PMID: 33765935

33. Wu CY, Chuang LL, Lin KC, Lee SD, Hong WH. Responsiveness, minimal detectable change, and mini- mal clinically important difference of the Nottingham Extended Activities of Daily Living Scale in patients with improved performance after stroke rehabilitation. Archives of physical medicine and rehabilitation. 2011; 92(8):1281–7. https://doi.org/10.1016/j.apmr.2011.03.008 PMID: 21807147

34. Taraldsen K, Thingstad P, Døhl Ø, Follestad T, Helbostad JL, Lamb SE, et al. Short and long-term clini- cal effectiveness and cost-effectiveness of a late-phase community-based balance and gait exercise program following hip fracture. The EVA-Hip Randomised Controlled Trial. PloS one. 2019; 14(11): e0224971. https://doi.org/10.1371/journal.pone.0224971 PMID: 31738792

35. Bjorgul K, Novicoff WM, Saleh KJ. American Society of Anesthesiologist Physical Status score may be used as a comorbidity index in hip fracture surgery. J Arthroplasty. 2010; 25(6 Suppl):134–7. https://doi.org/10.1016/j.arth.2010.04.010 PMID: 20537857

36. Kastanis G, Topalidou A, Alpantaki K, Rosiadis M, Balalis K. Is the ASA Score in Geriatric Hip Fractures a Predictive Factor for Complications and Readmission? Scientifica (Cairo). 2016; 2016:7096245. https://doi.org/10.1155/2016/7096245 PMID: 27293978

37. Mathew SA, Gane E, Heesch KC, McPhail SM. Risk factors for hospital re-presentation among older adults following fragility fractures: a systematic review and meta-analysis. BMC medicine. 2016; 14 (1):136. https://doi.org/10.1186/s12916-016-0671-x PMID: 27615745

38. Stabenau HF, Becher RD, Gahbauer EA, Leo-Summers L, Allore HG, Gill TM. Functional Trajectories Before and After Major Surgery in Older Adults. Ann Surg. 2018; 268(6):911–7. https://doi.org/10.1097/SLA.0000000000002659 PMID: 29356710

39. Gill TM, Han L, Gahbauer EA, Leo-Summers L, Allore HG. Prognostic Effect of Changes in Physical Function Over Prior Year on Subsequent Mortality and Long-Term Nursing Home Admission. Journal of the American Geriatrics Society. 2018; 66(8):1587–91. https://doi.org/10.1111/jgs.15399 PMID: 29719039

40. Banaszak-Holl J, Liang J, Quiñones A, Cigolle C, Lee IC, Verbrugge LM. Trajectories of functional change among long stayers in nursing homes: does baseline impairment matter? Journal of aging and health. 2011; 23(5):862–82. https://doi.org/10.1177/0898264311399759 PMID: 21436394

41. Thorngren KG, Norrman PO, Hommel A, Cedervall M, Thorngren J, Wingstrand H. Influence of age, sex, fracture type and pre-fracture living on rehabilitation pattern after hip fracture in the elderly. Disabil- ity and rehabilitation. 2005; 27(18–19):1091–7. https://doi.org/10.1080/09638280500056402 PMID: 16278177

42. Prestmo A, Saltvedt I, Helbostad JL, Taraldsen K, Thingstad P, Lydersen S, et al. Who benefits from orthogeriatric treatment? Results from the Trondheim hip-fracture trial. BMC geriatrics. 2016; 16:49. https://doi.org/10.1186/s12877-016-0218-1 PMID: 26895846

III

Postoperative outcomes in patients operated for extra- and intracapsular hip fractures – a secondary analysis of two randomized controlled trials

Shams Dakhil[1,2], Ane Djuv[3,4], Ingvild Saltvedt[5,6], Torgeir Bruun Wyller[1,2], Frede Frihagen[1,7], Lars Gunnar Johnsen[6,8], Kristin Taraldsen[9], Jorunn L. Helbostad[6], Leiv Otto Watne[2, 10, 11], Aksel Paulsen[3,12]

[1] Institute of Clinical Medicine, University of Oslo, Norway.

[2] Oslo Delirium Research Group, Department of Geriatric Medicine, Oslo University Hospital, Norway

[3] Department of Orthopaedic Surgery, Stavanger University Hospital, Stavanger, Norway

[4] Department of Clinical Medicine, Faculty of Medicine, University of Bergen

[3] Department of Geriatric Medicine, Akershus University Hospital, Lørenskog, Norway

[5] Department of Geriatric Medicine, St. Olav University Hospital, Trondheim, Norway

[6] Department of Neuromedicine and Movement Science, Norwegian University of Science and Technology (NTNU), Trondheim, Norway

[7] Department of Orthopaedic Surgery, Østfold Hospital Trust, Grålum, Norway.

[8] Orthopedic Trauma Unit, Department of Orthopedic Surgery, St. Olav University Hospital, Trondheim, Norway.

[9] Department of Rehabilitation Science and Health Technology, OsloMet – Oslo Metropolitan University, Oslo, Norway.

[10] Department of Geriatric Medicine, Akershus University Hospital, Lørenskog, Norway

[11] Institute of Clinical Medicine, Campus Ahus, University of Oslo, Oslo, Norway

[12] Department of Public Health, Faculty of Health Sciences, University of Stavanger

Corresponding author: Shams Dakhil (shamsdakhil@hotmail.com)

ORCID: 0000-0003-3549-4568

Errataliste

Navn kandidat: Shams Dakhil

Avhandlingstittel: Functional decline after a hip fracture - Long-term trajectories and the impact of orthogeriatric care and of fracture type

<u>Forkortelser for type rettelser:</u>

Cor – korrektur

Side	Sted	Originaltekst	Type rettelse	Korrigert tekst
55	Figur 3, boks med oversikt over Excluded i Trondheim	Aged >70 years (n=154)	Cor	Aged <70 years (n=154)