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Hip Fracture

Associated factors, mortality, and recovery

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Abstract

Background: Hip fracture is a major health concern among older adults, associated with substantial morbidity, mortality, and loss of independence. Despite advances in acute care and rehabilitation, outcomes following hip fracture remain highly variable. As the older population is heterogeneous with regard to health status, functional ability, and individual circumstances, a better understanding of factors associated with the hip fracture risk and associated mortality and recovery is needed.

Aim: The overall aim of this thesis was to examine factors associated with hip fracture and subsequent mortality, as well as older adults' experiences of recovery following hip fracture.

Methods: Four studies were conducted for this thesis using quantitative and qualitative approaches. Studies I and II were performed with data from the population-based Umeå 85+/Gerontological Regional Database cohort of 1,277 adults aged 85 years and older living in northern Sweden. In study I, sex-specific associations of potential risk factors with hip fracture during 5 years of follow up were examined using Cox and competing risk regression. In study II, factors associated with 1-year mortality among participants who sustained hip fractures were examined using Cox regression. Study III included 404 adults aged 70 years and older with hip fractures, and involved the examination of associations of dementia and depressive disorders with mortality at 12, 24, and 36 months using multivariable logistic regression. Study IV had a qualitative longitudinal design and included 13 older adults who were interviewed at 1, 4, and 12 months after hip fracture to explore their experiences of recovery. The data were analyzed using a longitudinal thematic approach.

Results: In study I, the incidence of hip fracture was similar among very old men and women, although the factors associated with the fracture risk differed by sex. Among women, greater functional independence was associated with an increased hip fracture risk. In study II, mortality following hip fracture was high, with nearly half of the very old adults dying within 1 year. Subtrochanteric fracture, previous stroke, and depressive disorders were associated with increased mortality. In study III, dementia

was consistently associated with increased mortality at 12, 24, and 36 months after hip fracture, whereas the association between depressive disorders and mortality varied across follow-up time points. The coexistence of dementia and depressive disorders did not contribute to the mortality risk in a simple additive manner. Study IV showed that older adults experienced recovery after hip fracture as a dynamic and non-linear process characterized by periods of progress, stagnation, and setback. Four interrelated themes representing key aspects of recovery were identified: engagement in daily activities, the fear of falling, family members' bridging of the support gap, and striving for independence.

Conclusions: The findings of this thesis research demonstrate that hip fracture in later life should be understood as a complex and life-altering event, rather than solely as an isolated orthopedic injury or an inevitable consequence of aging. The hip fracture risk and subsequent mortality and recovery are shaped by the interplay of functional, clinical, psychological, and social factors. The findings highlight the importance of recognizing heterogeneity among older adults and of considering individual vulnerability, exposure, and recovery experiences beyond chronological age alone.

Keywords: hip fracture, mortality, older adults, recovery, sex-specific risk factors, very old adults

List of studies

This thesis is based on the following studies, which are referred to in the text by their Roman numerals.

I. Olofsson, E., Gustafson Y., Mukka, S., Corneliusson, L., Tengman, E., Lindgren, L., & Olofsson., B. (2026). Sex-specific associations of factors with hip fracture in very old adults: findings from a population-based cohort study conducted in Northern Sweden. (Accepted 10-19-2026 in *European Geriatric Medicine*)

II. Olofsson, E., Gustafson, Y., Mukka, S., Corneliusson, L., Tengman, E., Lindgren, L., & Olofsson, B. (2026) Factors associated with one-year mortality after hip fracture in people older than 85 years in Northern Sweden. *European Geriatric Medicine*, 17(1):107-115.

III. Olofsson, E., Gustafson, Y., Mukka, S., Tengman, E, Lindgren, L., & Olofsson, B. (2023) Association of depressive disorders and dementia with mortality among older people with hip fracture. *BMC Geriatric*s, 23(1):135.

IV. Olofsson, E., Mukka, S., Wolf, O., Hailer, N., Tengman, E., Lindgren, L., Olofsson, B., & Adul, Å. (2026). Recovery during the first year after femoral neck fracture is a complex and non-linear journey: a longitudinal qualitative study. *International Journal of Orthopaedic and Trauma Nursing*, 60: 101256.

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Abbreviations

ADL	Activities of daily living
AI	Artificial intelligence
AO/OTA	Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association
BMI	Body mass index
CI	Confidence interval
CGA	Comprehensive geriatric assessment
DSM-IV	Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition
GDS-15	Geriatric Depression Scale (15-item version)
GERDA	Gerontological Regional Database
HipSTHeR	Hip Screws or (Total) Hip Replacement
HR	Hazard ratio
ICF	International Classification of Functioning, Disability and Health
IQR	Interquartile range
MMSE	Mini-Mental State Examination
OBS	Organic brain syndrome
PADL	Personal activities of daily living
PGCMS	Philadelphia Geriatric Center Morale Scale
RCT	Randomized controlled trial

Populärvetenskaplig sammanfattning (summary in Swedish)

Höftfraktur är en allvarlig skada som varje år drabbar omkring 17 000 personer i Sverige, främst äldre personer. Frakturen kan medföra långvarigt nedsatt funktionsförmåga, förlust av självständighet och ökad risk att dö. Samtidigt är äldre personer en heterogen grupp med stora individuella skillnader i hälsa, livssituation och förutsättningar för återhämtning. Kronologisk ålder säger därför inte i sig hur sårbar en person är eller hur livet efter en höftfraktur kommer att utvecklas.

Syftet med avhandlingen var att undersöka faktorer associerade med höftfraktur och dödlighet samt äldre personers erfarenheter av återhämtning efter höftfraktur.

De två första studierna baserades på data från befolkningsstudien Umeå 85+/GERDA och inkluderade personer som var 85 år eller äldre. Resultaten visade att risken att drabbas av höftfraktur i mycket hög ålder var ungefär lika stor bland kvinnor och män, men att de faktorer som var förknippade med risken skilde sig mellan könen. Bland kvinnor var en högre grad av självständighet i vardagliga aktiviteter förknippad med ökad en risk. Detta kan tyda på att risken för höftfraktur inte enbart hänger samman med skörhet, utan även med i vilken utsträckning en person rör sig och utsätts för situationer där fall kan inträffa (Studie I).

Dödligheten efter höftfraktur var hög, där nästan hälften av de allra äldsta personerna avled inom ett år. Risken att dö var inte enbart kopplad till kronologisk ålder, utan snarare till bakomliggande sjukdomar och sårbarhet. Depression, tidigare stroke och subtrokantär fraktur var förknippad med ökad dödlighet (Studie II).

I den tredje studien undersöktes hur demenssjukdom och depression var relaterade till dödlighet under de tre första åren efter en höftfraktur. Resultaten visade att demenssjukdom, både som enskilt tillstånd och i kombination med depression, var förknippad med ökad dödlighet vid

samtliga uppföljningstillfällen. Däremot sågs inget statistiskt säkerställt samband mellan enbart depression och ökad dödlighet (Studie III).

Den fjärde studien baserades på upprepade intervjuer med äldre personer under det första året efter höftfraktur. Återhämtningen beskrevs som en föränderlig process där framsteg kunde följas av bakslag. Möjligheten att klara vardagliga aktiviteter, rädsla för att falla igen, stöd från anhöriga och strävan efter självständighet var centrala aspekter av hur återhämtningen upplevdes. För flera deltagare kvarstod svårigheter ett år efter frakturen (Studie IV).

Sammantaget visar avhandlingen att höftfraktur senare i livet inte enbart bör förstås som en ortopedisk skada eller som en följd av hög ålder. Risken att drabbas, dödligheten efter frakturen och upplevelsen av återhämtning är kopplade till flera olika faktorer, däribland fysisk funktionsförmåga, sjukdomar och psykiskt mående. Vård och stöd behöver därför utgå från den enskilda personens förutsättningar, behov och mål. Återhämtning handlar inte bara om att läka en fraktur, utan också om att återfå trygghet, självständighet och möjlighet att leva vardagen på egna villkor.

Thesis at a glance

Study I: To examine sex differences in factors associated with hip fracture among very old adults in Northern Sweden

Design: Population-based cohort study based on Umeå 85+/GERDA including 1,277 adults aged 85, 90 or ≥ 95 years, of whom 184 sustained a hip fracture during follow-up.

Conclusion: Hip fracture incidence was similar in very old women and men, but associated factors differed between the sexes. For example, smoking and higher functional independence were associated with increased hip fracture risk in women.

Study II: To explore factors associated with one-year mortality risk after hip fracture among very old adults in Northern Sweden.

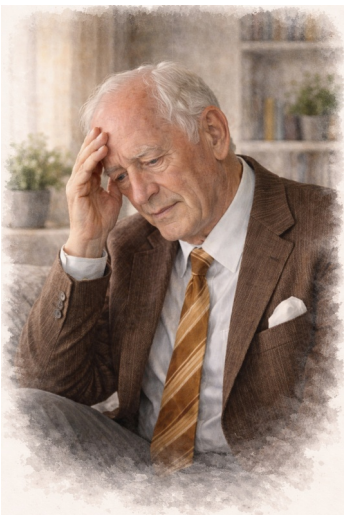
Design: Population-based cohort study based on Umeå 85+/Gerda, including 184 adults 85, 90 or ≥ 95 years who sustained a hip fracture.

Conclusion: Nearly half of the participants died within one year after hip fracture. Mortality was associated with depressive disorders, prior stroke and subtrochanteric fracture whereas overweight or obesity were associated with lower mortality risk.

Study III: To investigate whether dementia with depressive disorders were associated with mortality risk at 12, 24 and 36 months after hip fracture among older adults.

Design: Retrospective analysis of two randomized controlled trials including 404 adults aged 70 years and older with acute hip fracture.

Conclusion: Dementia with depressive disorder have increased mortality risk at 12, 24, and 36 months after hip fracture.



Study IV: To explore older adults' experiences of recovery during the first year after femoral neck fracture

Design: Longitudinal qualitative interview study including 13 adults aged 75 years or older with femoral neck fracture. Semi-structured interviews were conducted at 1, 4, and 12 months after fracture.

Conclusion: Recovery after hip fracture was experienced as a complex and non-linear process shaped by physical, emotional, and social factors.

(AI generated image)

Introduction

Hip fracture is one of the most serious injuries affecting older adults, and it is a major public health challenge due to its associations with functional decline [1], loss of independence [2], increased mortality [3-5], and substantial healthcare costs [6]. In Sweden, approximately 17,000 individuals sustain hip fractures each year, and the mean age of this group exceeds 80 years [7, 8]. Despite advances in surgical techniques and rehabilitation, outcomes of hip fracture remain poor for many patients [9, 10]. The associated mortality rate is high, particularly among very old adults and individuals with cognitive impairment or depressive disorders, and many survivors experience long-term limitations on mobility, activities of daily living (ADL), and participation in everyday life [11, 12].

Research on hip fracture has traditionally focused on biomedical aspects, such as fracture characteristics, treatment methods, and postoperative complications [13-15]. Although perspectives on these factors are essential, they provide only a partial understanding of outcomes after hip fracture in later life. Age is frequently used to categorize older adults in research and healthcare contexts [16]. However, chronological age alone does not adequately capture the substantial heterogeneity in health, functional capacity, and vulnerability among older adults [17]. This heterogeneity is also relevant when considering the risk of sustaining a hip fracture. Although the incidence of hip fracture increases markedly with age at the population level [18], individual risks remain heterogeneous, and the relevance of established risk factors may differ in very old age [19].

At the same time, the consequences of hip fracture extend beyond medical and functional outcomes. A hip fracture may disrupt everyday life [20], challenge a person's sense of independence and security, and increase their reliance on others [21]. Recovery may thus involve not only the regaining of physical function, but also adaptation to changes in everyday life and the finding of ways to regain independence and confidence. An understanding of how older adults experience recovery is thus important for the identification of challenges, needs, and sources of support that may otherwise remain unrecognized. Such knowledge can contribute to the

delivery of care and rehabilitation that are more responsive to what matters to individuals.

Consequently, there is a need for approaches that extend beyond a simplified age-based understanding of hip fracture to consider the diverse health, functional, psychological, and social circumstances that may shape outcomes and recovery in later life. Such perspectives may contribute to a more nuanced understanding of why outcomes differ among individuals of similar age and aid the identification of individual needs and opportunities for support during recovery.

This thesis thus examines hip fracture in later life as a complex and life-altering event, with the integration of perspectives on risk, mortality, and recovery. Quantitative analyses of factors associated with hip fracture and mortality are combined with qualitative explorations of older adults' lived experiences of recovery, with the goal of contributing knowledge that may support more individualized, equitable, and age-sensitive care for older adults with hip fracture.

Background

Older adults

There is no universally accepted chronological age at which a person becomes an older adult [17]. Although the age of 65 years is frequently used as a pragmatic threshold in research and health-related guidelines, definitions of "older adult" vary across studies and contexts [22, 23]. In this thesis, "older adults" is used as a broad and inclusive concept referring to individuals in later life. Age criteria differed across the included studies, reflecting the respective study populations and designs. The terminology used to describe later phases of older age also varies. Terms such as "oldest old" and "very old adults" have been applied to different chronological age thresholds [24]. In this thesis, "very old adults" refers to individuals aged 85 years and older, corresponding to the population enrolled in studies I and II and consistent with its use in previous population-based research [25-27]. These terms describe study populations and do not imply that individuals in a given age category constitute a homogeneous group.

Chronological age alone does not adequately capture the substantial variation in health status, functional ability, and life circumstances among older adults. Vulnerability in later life is multidimensional and may reflect physical, functional, cognitive, psychological, and social circumstances. These circumstances may increase an individual's susceptibility to adverse outcomes or affect their capacity to respond to illness or injury. Vulnerability may thus vary considerably among individuals of similar chronological age [28, 29].

The number of people aged 80 years and older is projected to triple between 2020 and 2050, reaching 426 million worldwide [30]. In Sweden, people aged 80 years and older constituted just over 6% of the population in 2025, and this proportion is projected to increase to 11% by 2070 [31]. However, population aging should not be equated with increasing ill health or dependency at the individual level [32]. Rather, this demographic change highlights the importance of healthcare and social services' ability to respond to diverse and changing needs in later life.

Falls are a leading cause of injury among older adults, and the incidence of fall-related injuries increases with age. The fall risk reflects complex interaction among physiological, cognitive, psychological, and environmental factors [33, 34], including impaired balance, reduced muscle strength [35], multimorbidity [36, 37], medication use [38], cognitive impairment, and depressive symptoms [33]. Although only a minority of falls result in hip fracture, more than 90% of hip fractures among older adults are caused by falls [5, 39]. Outcomes following hip fracture may differ according to health and functional status [40], as well as cognitive, psychological, and social circumstances [41, 42]. In this heterogeneous population, cognitive impairment, dementia, and depressive disorders are particularly important conditions to consider.

Dementia

"Dementia" is an umbrella term describing a clinical syndrome characterized by progressive cognitive decline that interferes with daily functioning [43]. In the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders, conditions previously classified as dementia were subsumed under the term "major neurocognitive disorder" [44]. The term "dementia," however, remains accepted and widely used in clinical and research contexts [44]. It is also used in this thesis because diagnoses were established according to the criteria of the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) in studies I-III, and it was used in the included studies. Dementia encompasses a group of conditions that may affect memory, orientation, executive function, language, and visuospatial ability, with its clinical presentation and progression varying according to the underlying pathology [43, 45]. Dementia may also involve behavioral and psychological symptoms, including apathy, agitation, personality changes, and social withdrawal [46].

Dementia is a leading cause of disability and dependency among older adults worldwide [45], and it affects approximately 130,000-150,000 individuals in Sweden [47]. As cognitive decline progresses, individuals with the condition may become increasingly dependent on support for everyday activities and other aspects of daily life [48].

Among older adults with hip fracture, dementia and cognitive impairment are common and have been associated with poorer outcomes following the injury, including increased mortality, impaired physical function, and increased dependence [49-52]. Several factors may contribute to an increased susceptibility to falls among people with dementia, including impairments in gait, balance, and functional ability, as well as medication-related factors [53].

Cognitive impairment may present additional challenges during recovery and rehabilitation after hip fracture [49, 51]. Importantly, these challenges may not solely reflect individual cognitive or health-related factors. People with dementia have been shown to be less likely to receive rehabilitation than are those without dementia [54, 55], despite evidence that they can benefit from rehabilitative interventions [55, 56]. Such disparities suggest that poorer outcomes may reflect not only individual vulnerability, but also differences in access to rehabilitation and opportunities for recovery. Rehabilitation services may not always be designed to meet the complex needs of people with cognitive impairment, and individualized approaches may be required to facilitate engagement in rehabilitation [56].

Dementia frequently coexists with other conditions that further contribute to vulnerability in later life. In particular, depressive disorders are common among individuals with cognitive impairment [57, 58]. The coexistence of cognitive impairment and depressive disorders may complicate assessment and care, and is particularly relevant in the context of outcomes following hip fracture.

Depressive disorders

Depressive disorders are common among older adults and constitute a significant but often underrecognized health concern. Depression is characterized by persistent low mood, reduced interest, fatigue, and impaired functioning over an extended period of time [59]. In Europe, the prevalence of major depressive disorders among older adults has been estimated to be approximately 13% [60], with higher rates of depressive disorders reported among very old adults [25].

Depression in later life may differ from early-onset depression in terms of etiology and clinical presentation, and it has been associated with vascular and cognitive factors [61, 62]. Symptoms may also be expressed in ways that are not readily recognized as depression. Older adults may describe fatigue, impaired concentration, apathy, social withdrawal, and/or loss of meaning in life, rather than explicitly expressing sadness [63, 64]. Depressive disorders may consequently remain underrecognized, particularly when symptoms are attributed to aging or coexisting physical illness [65].

Depressive disorders and depressive symptoms have been associated with increased mortality [50, 66, 67] and poorer functional recovery following hip fracture [68, 69], although findings for mortality have not been consistent across studies. Depressive symptoms may also emerge or persist during the recovery period; in one prospective study, 14% of individuals without major depression at the time of hip fracture developed major depressive disorders following the injury [70]. Persistent depressive symptoms during recovery have also been associated with poorer physical performance, although the strength of this association has varied across studies [68]. Depression may thus be both a pre-existing vulnerability and a condition that emerges during recovery after hip fracture, with potential implications for rehabilitation and adaptation.

The coexistence of depressive disorders and dementia may contribute to increased vulnerability and complicate assessment and care. An understanding of depression in relation to dementia is thus essential to capture the complexity of outcomes after hip fracture in older adults.

Hip fracture

Hip fractures involve the proximal femur and can be classified broadly based on anatomical location as femoral neck, trochanteric, and subtrochanteric fractures. Surgical treatment is the standard of care for most hip fractures in Sweden [71-73]. It is generally guided by fracture characteristics, including the location and degree of displacement, in combination with patient-related factors such as comorbidity, functional status, and physiological reserve [73-75].

Epidemiology

Hip fracture predominantly affects older adults and is among the most serious injuries in later life. In Sweden, the mean age of individuals sustaining hip fractures is approximately 82 years, and the majority of patients are women [5, 7, 76].

The incidence of hip fracture increases markedly with age and is highest among the oldest segments of the population [77, 78]. Although age-specific incidence rates have stabilized or declined in Sweden and several other high-income countries [79-81], the absolute burden of hip fracture remains substantial due to population aging and the rapidly growing number of people reaching very old age [77, 78, 81].

Female sex is an established risk factor for hip fracture [78, 81]. Sex differences in the hip fracture risk have been attributed to several factors, including differences in bone density and hip anatomy [82, 83]. However, the magnitude of the sex difference in the hip fracture incidence varies with age, with the difference between women and men becoming smaller in the oldest age groups [84]. These age-related differences raise questions about whether sex-specific risk patterns established in broader populations of older adults also apply in very old age [19].

Most hip fractures occurring in older adults result from low-energy trauma, typically falls from standing height [5, 39]. The occurrence of a hip fracture reflects interplay between the risk and characteristics of a fall and the ability of the bone to withstand the resulting impact [39]. Established risk factors include increasing age, low body mass index (BMI), chronic disease,

cognitive impairment, and impaired physical function [33, 85-87]. Older adults' functional ability and mobility may be particularly important factors to consider, as they may influence the susceptibility to falls as well as exposure to environmental hazards or situations in which a fall can occur [88]. The relative importance of risk factors may change with advancing age, and the relationship between functional ability and the hip fracture risk may be particularly complex in very old age [39, 89].

Studies specifically examining factors associated with hip fracture in very old age remain limited [26]. Reported sex-specific differences in factors associated with hip fracture have not been derived specifically from populations of very old adults [89-91]. Further knowledge of sex-specific risk patterns in very old adults is thus needed.

Fracture treatment

Although the surgical treatment of hip fractures is not a primary focus of this thesis, clinical distinctions in fracture types and treatments are relevant because they differed across the populations of the included studies. The fracture type may also be associated with outcomes following hip fracture [14]. Thus, an understanding of hip fracture as a heterogeneous clinical condition provides important context for the interpretation of differences in mortality and recovery among the included studies.

Undisplaced femoral neck fractures may be treated with internal fixation [15, 92], whereas displaced femoral neck fractures in older adults are often managed with hemiarthroplasty or total hip arthroplasty [3, 15]. Trochanteric fractures are commonly treated with sliding hip screws or cephalomedullary nails, depending on their stability [93]. Subtrochanteric fractures are generally treated with intramedullary fixation [94].

Surgery, however, represents only the initial phase of hip fracture care. Multidisciplinary postoperative care, early mobilization, and rehabilitation are also important components of the subsequent care trajectory [73].

Outcomes following hip fracture

Outcomes following hip fracture vary considerably among older adults. Some individuals regain functional ability and independence, whereas others experience persistent functional limitations, increased dependence, institutionalization, or death [40]. Factors associated with these outcomes include the pre-fracture functional status, comorbidity, nutritional status, cognitive impairment, depressive disorders, social support, and access to rehabilitation [14, 40-42, 55, 56].

In the context of this thesis, recovery and mortality after hip fracture are central. Mortality reflects survival following the injury, and recovery encompasses changes in physical function and independence as well as psychological well-being and the ability to resume everyday life. Thus, previous research on these outcomes and associated factors is considered in the following sections.

Recovery after hip fracture

Recovery and rehabilitation following hip fracture are closely related but conceptually distinct. Rehabilitation refers to interventions aiming to optimize function and reduce disability, whereas recovery can be understood more broadly as the process through which individuals regain or adapt their function, independence, and everyday life [95, 96]. From this perspective, recovery is not limited to objectively measurable outcomes such as physical function and independence, but also encompasses how individuals experience vulnerability, confidence, participation, and the ability to engage in meaningful everyday activities [97]. These considerations are complementary: measurable outcomes provide important information about changes in health and function, whereas older adults' experiences provide insight into the meaning of changes in everyday life.

Functional outcomes after hip fracture are influenced by multiple interacting factors, including the pre-fracture functional capacity, cognitive impairment, depressive disorders, comorbidity burden, nutritional status, and access to social and professional support [40-42]. The care provided may also shape recovery. The application of orthogeriatric care models

integrating interdisciplinary teams and comprehensive geriatric assessment (CGA) has been associated with improved outcomes following hip fracture [98-102]. Multidisciplinary rehabilitation, including early mobilization, is also an important component of postoperative recovery and may improve functional outcomes [103-105].

In Sweden, the length of hospital stay following hip fracture has decreased substantially in recent decades [9]. Consequently, much of the longer-term rehabilitation and recovery process extends beyond acute hospital stays. Rehabilitation may continue in patients' homes, with the implementation of interventions aiming to support mobility, functional ability, and independence in activities [106]. Home-based rehabilitation may achieve functional outcomes comparable to inpatient rehabilitation [98, 107], although individual needs and circumstances may influence the suitability of different rehabilitation settings. As recovery continues beyond the hospital, individuals increasingly need to manage everyday life in their own contexts, where support from family members and continued professional support may play important roles [12].

Beyond the acute phase of hip fracture treatment, many older adults experience persistent reduced mobility, fear of falling, and other physical and psychological challenges that may continue to influence their everyday lives and participation during recovery [11, 108]. Individuals living with dementia or cognitive impairment may be particularly vulnerable to poorer functional outcomes and increased dependence [52]. Depressive disorders and depressive symptoms are also common following hip fracture and may further complicate functional recovery [65, 109].

Recovery after hip fracture cannot be fully understood as linear progression toward restored physical function. Evidence suggests that it is a dynamic and individualized process characterized by fluctuations, setbacks, and periods of adaptation over time [12, 95]. Recovery may involve not only physical improvement, but also emotional adjustment, the renegotiation of identity, and re-engagement in meaningful activities [110, 111]. In this context, fear of falling is a particularly influential aspect of recovery after hip fracture. Even when patients' physical function improves, persistent fear

may lead to activity restriction, reduced confidence, and social withdrawal, thereby affecting their long-term participation and quality of life [11, 112].

Taken together, findings from previous research indicate that recovery after hip fracture extends beyond biological healing and the restoration of physical function. It may be understood as a multidimensional and individualized process involving physical, psychological, and social dimensions, unfolding over time and within the context of everyday life. However, a full understanding of how these dimensions evolve and interact requires attention to older adults' experiences throughout the recovery process. A longitudinal perspective would be particularly valuable, capturing how patients' experiences, challenges, and support needs change over time [113].

Mortality after hip fracture

Mortality following hip fracture remains high among older adults; commonly reported mortality rates for the first year are within the range of 20–30% [114, 115]. Among people aged 90 years and older, 1-year mortality rates range from approximately 38% to 45% [116, 117]. Excess mortality may also persist for several years following the injury [78, 117]. However, survival after hip fracture varies substantially, and the identification of outcome-influencing factors present before and at the time of injury may enable a more nuanced understanding of the mortality risk than does the consideration of chronological age alone [40, 118, 119].

Although dementia and depressive disorders and symptoms have been associated separately with increased mortality following hip fracture, knowledge about their combined effects in older adults is more limited. In addition, mortality following hip fracture in very old adults remains understudied [116, 120]. Further knowledge in both of these domains is thus needed.

Rationale

Hip fracture is a common and serious injury in older adults, and it is associated with substantial functional decline, loss of independence, and mortality. The incidence of hip fracture increases with age, although evidence concerning factors associated with hip fracture specifically among very old adults (those aged ≥ 85 years) remains comparatively limited.

Several biological, clinical, and lifestyle-related factors have been associated with hip fracture. However, their relative importance may differ in very old age, and evidence pertaining to very old adults remains limited. In particular, sex-specific patterns in this population have received limited attention, despite indications that factors associated with hip fracture may differ between women and men.

Mortality following hip fracture is well documented, yet evidence regarding factors associated with mortality among very old adults is insufficient. Dementia and depressive disorders have been associated with mortality following hip fracture, but the effects of these conditions have been examined separately in most studies, despite their frequent coexistence in older adults. Evidence regarding their co-occurrence is limited and has been derived mainly from studies involving shorter follow-up periods and younger populations.

Recovery following hip fracture has traditionally been evaluated through the examination of clinical and functional outcomes. Although qualitative studies have provided important insights into older adults' experiences, longitudinal knowledge of how recovery evolves and is experienced in everyday life is insufficient. An improved understanding of how patients' experiences, challenges, and support needs change throughout the recovery process may provide insights that are not captured by the consideration of conventional clinical and functional outcomes.

By bringing together quantitative and qualitative perspectives, this thesis seeks to provide a more comprehensive understanding of hip fracture in later life.

Aims of the thesis

The overall aim of this thesis was to examine factors associated with hip fracture and subsequent mortality among older adults, as well as these individuals' experiences of recovery following hip fracture.

The specific aims of the investigations were:

Study 1: To examine sex-specific associations of factors with hip fracture among very old adults in northern Sweden.

Study 2: To explore factors associated with the 1-year mortality risk after hip fracture among very old adults (those aged ≥ 85 years) in northern Sweden.

Study 3: To investigate whether dementia with depressive disorders affects the mortality risk at 12, 24, and 36 months after hip fracture among older people.

Study 4: To explore older adults' recovery experiences during the first year after femoral neck fracture.

Methods

In the studies conducted for this thesis, quantitative and qualitative methods were applied to examine hip fracture in later life from complementary perspectives (Table 1). The quantitative studies were conducted to examine factors associated with hip fracture and subsequent mortality, generating knowledge about patterns of risk and adverse outcomes. The qualitative study was conducted to explore how older adults experience recovery from hip fracture, and changes in everyday life over time.

Table 1. *Overview of designs, participants, data collection, and analysis for studies I-IV.*

	Design	*No. of participants*	*Data collection*	*Baseline data collection periods*	*Data analysis*
I	Population-based cohort study with prospective follow up	1,277	Structured home visits and medical record review	2000-2002, 2005-2007, 2010-2012, and 2015-2017	Descriptive statistics, Cox proportional-hazards regression, Fine-Gray competing risk regression
II	Population-based cohort study	1,277	Structured home visits and medical record review	2000-2002, 2005-2007, 2010-2012, and 2015-2017	Descriptive statistics, Cox proportional-hazards regression
III	Retrospective analysis of two RCTs	404	Clinical assessments and medical record review	2000-2002 and 2008-2011	Descriptive statistics, multivariable logistic regression
IV	Longitudinal qualitative study	13	Semi-structured individual interviews at 1,4, and 12 months	2021-2023	Reflexive thematic analysis with a longitudinal thematic approach

RCT, randomized controlled trial.

Study contexts, designs, and overviews

Studies I and II

Studies I and II were conducted with data from the Umeå 85+/Gerontological Regional Database (GERDA), compiled as part of a population-based study examining the health and living conditions of very old adults living in the community and in residential care settings. The GERDA study is a collaboration between Umeå University in Sweden and Åbo Akademi University, Novia University of Applied Science, Seinäjoki University of Applied Science, and Åland University of Applied Science in Finland.

Data were collected in waves at approximately 5-year intervals in urban and rural municipalities in Västerbotten County, Sweden (2000-2002, 2005-2007, 2010-2012, and 2015-2017), and Österbotten County, Finland (2006 and 2011). Studies I and II were conducted exclusively with data from the Swedish study population in Västerbotten County.

Participants were selected from national population registers using systematic sampling procedures based on dates of birth. From a randomized starting point, every second individual aged 85 years, all individuals aged 90 years, and all individuals aged ≥ 95 years were invited to participate. Participants who had taken part in earlier waves were also invited to participate in subsequent data collection.

All eligible individuals received written information about the GERDA study and were subsequently contacted by telephone and invited to participate. When there were indications of cognitive impairment, a relative was also consulted regarding participation. Home visits (at participants' homes and residential care facilities) were scheduled for individuals who agreed to participate. During data collection, supplementary information was obtained from relatives or caregivers when needed.

Study III

Study III was conducted with data from two randomized controlled trials (RCTs) conducted at Umeå University Hospital, Sweden. In both RCTs,

eligible patients received oral and written study information. For patients with cognitive impairment, next of kin was consulted before inclusion.

The first RCT included 199 consecutive participants aged ≥ 70 years with femoral neck fractures who had been admitted to the orthopedic department between May 2000 and December 2002. The overall aim of the trial was to evaluate a multidisciplinary postoperative intervention program focused on the prevention, detection, and treatment of postoperative complications, particularly delirium and inpatient falls. Participants were randomized to postoperative care in a geriatric ward with a structured intervention program based on CGA or to conventional postoperative care in an orthopedic ward [121].

The second RCT included 205 participants aged ≥ 70 years with femoral neck or trochanteric hip fractures who were recruited between May 2008 and June 2011. The overall aim of the trial was to evaluate the effects of early discharge followed by interdisciplinary geriatric home rehabilitation relative to those of continued in-hospital geriatric care and rehabilitation based on a multifactorial intervention program [107].

In both trials, trained research staff assessed participants during the early postoperative period. For study III, data from the two trials were combined and mortality was analyzed retrospectively.

Study IV

In study IV, participants were recruited from the Hip Screws or (Total) Hip Replacement (HipSTHeR) trial, a national, multicenter, register-based RCT initiated in 2019 and conducted across 29 orthopedic centers in Sweden [122]. The HipSTHeR trial included approximately 1,440 patients aged ≥ 75 years with nondisplaced or minimally displaced (Garden I-II) femoral neck fractures who were eligible for treatment with internal fixation or hip arthroplasty. The primary aim of the trial was to compare the outcomes of these treatments in terms of reoperation and mortality rates.

Study IV was conducted between July 2021 and June 2023. It involved the examination of recovery experiences during the first year after femoral neck fracture with a qualitative subsample of HipSTHeR trial participants.

Participants

Studies I and II

Studies I and II were conducted with data from participants who had completed a home visit and provided consent for medical record review in the GERDA study. For individuals who had participated in multiple data collection waves, only data from the first assessment occasion were included. Only participants from Sweden were included to enable the complete verification and classification of hip fractures through medical record review, thereby ensuring consistent outcome ascertainment across the study population. The cohort comprised 1,277 participants, of whom 184 sustained hip fractures during the 5-year follow-up period (Figure 1).

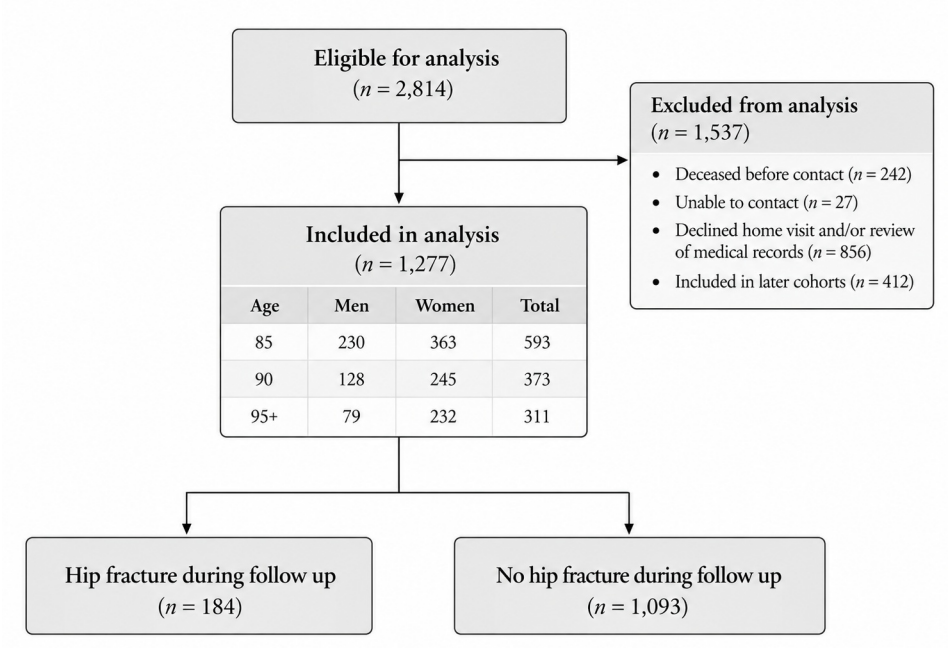


Figure 1. *Flowchart of participant selection for studies I and II from the GERDA study population.*

Study III

Study III was conducted with data from all 404 participants in the original RCTs. Participants were residents of Umeå municipality. The exclusion criteria differed somewhat between trials. In the first RCT [121], patients with severe rheumatoid arthritis, hip osteoarthritis, pathological or hospital-acquired hip fracture, or renal failure, as well as those who were bedridden before fracture, were excluded. In the second RCT [98], patients with pathological or hospital-acquired hip fractures were excluded. Participants with cognitive impairment and/or dementia were eligible for inclusion in both trials.

Study IV

Study IV was conducted with participants recruited from the HipSTHeR trial at Umeå and Uppsala University hospitals in Sweden. Participants were enrolled in the HipSTHeR trial in the acute phase (within 72 hours of fracture). Patients with stress, pathological, or peri-implant femoral neck fractures were excluded [122]. The same eligibility criteria were applied in study IV, with the additional requirement that participants were able to understand and speak Swedish.

The author or another member of the research team approached eligible participants during their hospital stays following femoral neck fracture. The author contacted participants who were not approached during hospitalization by telephone. Written study information and a consent form were then sent by mail, and participants returned the signed consent form before the first interview.

Of 19 individuals invited to participate, 16 provided informed consent. Two individuals died before the first interview and one could not be reached despite repeated telephone calls, resulting in a final study sample of 13 participants (Figure 2).

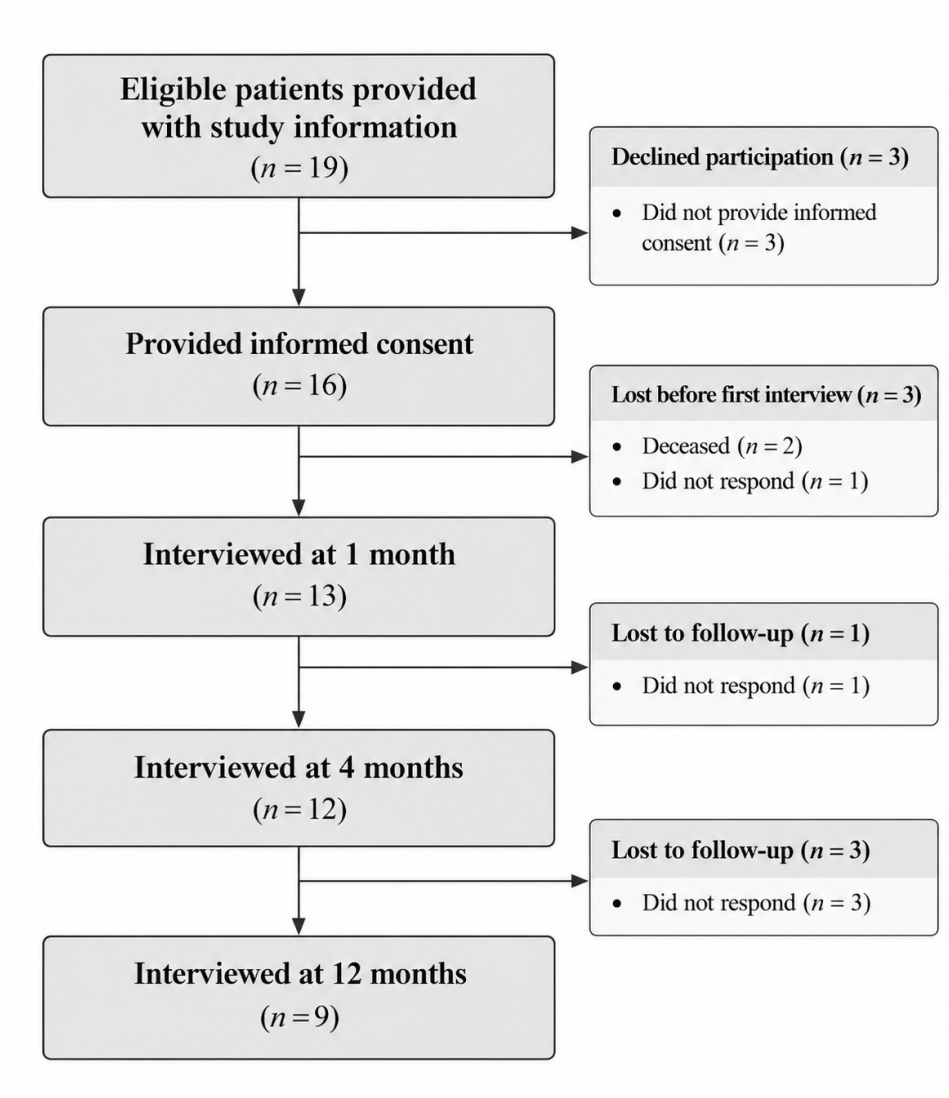


Figure 2. *Flowchart of participant recruitment and longitudinal follow up in study IV.*

Data collection

Studies I and II

Trained healthcare professionals (physicians, nurses, physiotherapists, and medical students) collected baseline data during home visits using standardized interviews and assessments following a study protocol inspired by CGA. Information was obtained about participants' sociodemographic characteristics, medical conditions, medication use, functional ability, cognitive function, nutritional status, and psychosocial factors. Additional information was obtained from care personnel and/or relatives acting as proxy respondents when participants required such support. Medical records were reviewed to verify diagnoses and medication use. Information on all invited participants' age and sex was obtained from population registers. Dates of death were obtained from medical records.

Information on hip fracture occurrence and classification was obtained through medical record review covering the period from January 1, 1980, to February 1, 2023. Hip fractures were verified using medical records and radiographic reports and classified as femoral neck, trochanteric, and subtrochanteric fractures according to the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) system [123].

Study III

Trained research staff collected baseline data during the early postoperative period using clinical assessments and medical record reviews. Information was obtained from participants, relatives when appropriate, and medical records. Data on participants' sociodemographic characteristics, medical conditions, cognitive function, depressive symptoms, functional status, and other clinical characteristics relevant to the study were collected.

Study IV

Data were collected through semi-structured individual telephone interviews conducted approximately 1, 4, and 12 months after femoral neck fracture. The research team collaboratively developed an interview guide inspired by the International Classification of Functioning, Disability and Health (ICF) [124], as well as clinical pre-understanding and previous research. During the interviews, the author asked open-ended questions about participants' experiences of recovery and everyday life following fracture. The first question was "*Please tell me about how your hip is functioning today?"*. Follow-up questions were used to explore participants' experiences in greater depth.

To capture changes in participants' experiences over time, the author reviewed each participant's previous interview before conducting the interviews at 4 and 12 months. This enabled her to ask follow-up questions addressing experiences and issues raised in earlier interviews, and related changes or developments over time.

Two senior researchers with experience in qualitative interviewing attended the initial interviews and asked supplementary questions at the end when relevant. Following each of these interviews, the senior researchers provided feedback to the author on the interviewing process.

All interviews were audio-recorded and transcribed verbatim. In total, 34 interviews with a median duration of 36 (range, 23-93) minutes were conducted.

Clinical assessments and diagnoses

An overview of the conditions assessed and instruments and measures used in studies I-III is provided in Table 2.

Table 2. *Overview of clinical conditions assessed and instruments used in studies I-III.*

Variable/measure	Short description	Study I	Study II	Study III
Clinical conditions				
Dementia	Diagnosed according to DSM-IV criteria, included relevant assessments and observations.	X	X	X
Depressive disorders	Diagnosed according to DSM-IV criteria, included relevant assessments and observations.	X	X	X
Combination of dementia and depressive disorders	Coexistence of both conditions.	X	X	X
Vision impairment	Not able to read 5-mm letters with or without glasses.	X	X	X
Hearing impairment	Not able to hear normal conversation tone from 1 m distance with or without hearing aids.	X	X	X
Body Mass Index	Body weight and height were measured to calculate weight (kg)/height (m)^2.	X	X	
Assessment instruments				
Mini Nutritional Assessment	Nutritional status screening. Range 0–30, higher scores indicate better nutritional status.	X	X	
Mini-Mental State Examination	Cognitive function. Range 0–30. Scores ≤ 23 indicate cognitive impairment.	X	X	X
Geriatric Depression Scale	Screening for depressive symptoms. Range 0–15, with 0–4 categorized as normal.	X	X	X
Barthel ADL Index	Functional independence in daily activities. Range 0–20, with 20 indicating total independence in personal ADL.	X	X	
Selected parts of Katz ADL Index	Independence in personal activities of daily living.			X
The Philadelphia Geriatric Center Morale Scale	Psychological well-being/morale. Range 0–17, higher scores indicate higher morale.	X	X	
Gait speed (m/s)	Walking speed over 2.4 m with or without walking aid.	X		
Independence in transfer	Able to transfer with no supervision, direction or personal assistance.	X	X	X

DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, 4th revision; ADL, activities of daily living.

Mini-Mental State Examination

The Mini Mental State Examination (MMSE) is used widely to assess global cognitive function in the domains of orientation, registration, attention and calculation, recall, and language [125]. Total scores range from 0 to 30, with higher scores indicating better cognitive function [126]. Although the MMSE is commonly used to identify cognitive impairment, it is not a diagnostic instrument for dementia, and individuals' performance may be influenced by factors such as age, education, language, and sensory impairment [127]. In this thesis, as is common, the score of 23 was used as the cut-off indicating cognitive impairment [128]. However, previous research suggests that optimal cut-off values may vary according to educational level, with lower thresholds proposed for individuals with fewer years of education [129]. The MMSE has demonstrated acceptable validity and reliability in older populations [130].

Geriatric Depression Scale

The 15-item Geriatric Depression Scale (GDS-15) is a self-reported screening instrument developed to assess depressive symptoms in older adults [131]. It consists of 15 yes/no questions assessing respondents' depressive symptoms during the past week. Total scores range from 0 to 15, with higher scores indicating more depressive symptoms. Scores of 0-4 are considered to be normal, scores of 5-9 indicate mild depressive symptoms, and scores of 10-15 indicate moderate to severe depressive symptoms [132].

The GDS-15 has demonstrated good validity and reliability in older populations [133], including among very old adults [134]. It has also been shown to perform well with individuals with mild to moderate cognitive impairment, particularly those with MMSE scores ≥ 10 [134]. In this thesis, the GDS-15 was used as part of the overall assessment of depressive disorders.

Functional status and physical performance

Functional status and physical performance were assessed using standardized instruments and variables reflecting mobility and independence in daily living.

The Barthel ADL Index is an ordinal scale that measures independence in personal activities of daily living (PADL). It comprises 10 items, with total scores ranging from 0 to 20 and higher scores indicating greater independence [135, 136]. The Barthel ADL Index has demonstrated adequate reliability and responsiveness for the assessment of changes in functional ability in older populations [137]. It has also been used as a predictor of healthcare utilization, including hospital admission and the need for home care services [138]. In this thesis, the Barthel ADL Index was used in studies I and II. In study I, a non-linear association was identified between Barthel ADL Index scores and hip fracture. Scores were thus categorized into five equally sized intervals (0-4, 5-8, 9-12, 13-16, and 17-20) representing increasing levels of functional independence.

In addition, an "independence in transfer" variable was used in studies I-III. This variable was derived from item 8 of the Barthel ADL Index and dichotomized to indicate whether the participant was able to transfer independently indoors, with or without the use of a walking aid.

In study III, ADL performance was assessed using the Barthel ADL Index [135] and the ADL Staircase, which incorporates the Katz Index of Independence in ADL [139]. Although both indices are used to assess independence in PADL, the specific activities included and scoring procedures differ between them. The Katz Index assesses feeding, continence, transferring, toileting, bathing, and dressing. ADL performance is classified from A to G, with A indicating independence in all activities. In addition to the Katz Index items, the ADL Staircase includes four items assessing instrumental ADL: cooking, cleaning, shopping, and public transport. ADL Staircase scores range from 0 to 10, with 0 indicating independence in all activities. In study III, pre-fracture functional ability was assessed using two dichotomous variables: independence in PADL, derived from the Katz ADL Index, and independence in walking indoors, assessed separately. Both instruments are considered to be suitable for the assessment of older adults' functional ability [126, 140].

In study I, gait speed was assessed over a distance of 8 feet (2.4 m). Participants were instructed to walk at their usual pace, with or without the

use of a walking aid. The test was performed twice, and the mean gait speed was calculated in meters per second. Gait speed is a well-established measure of older adults' physical performance, and it has been shown to predict adverse outcomes, including mortality [141].

Additional instruments and measures

Several other measures were used to characterize participants' nutritional status and psychological well-being.

The Mini Nutritional Assessment is a screening tool that was used in studies I and II to assess older adults' nutritional status. It includes items covering dietary intake, weight loss, mobility, health, and neuropsychological problems, as well as anthropometric measures. Total scores range from 0 to 30, with lower scores indicating poorer nutritional status and an increased risk of malnutrition [142].

In studies I and II, participants' BMIs were calculated from their measured height and weight (kg/m^2). Participants were categorized as underweight (BMI < 22 kg/m^2), normal weight (BMI = 22-29 kg/m^2), and overweight/obese (BMI ≥ 30 kg/m^2) [143].

The Philadelphia Geriatric Center Morale Scale (PGCMS) was used in studies I and II to assess participants' psychological well-being and quality of life [144]. The scale consists of 17 dichotomous items, with higher scores indicating higher morale. The PGCMS has been used and validated in very old populations [145].

Hearing and vision impairment were assessed in studies I-III. They were defined as the inability to hear a conversation at normal speaking volume and distance (1 meter) with or without participants' hearing aids, and the inability to read large (5-mm-tall) text at a normal distance with or without participants' glasses, respectively.

Diagnosis of dementia

At the end of data collection, an experienced consultant geriatrician verified dementia diagnoses among all participants based on all available

information, including medical records, medication use, educational level, and baseline assessments. These assessments comprised the MMSE, GDS-15, Barthel ADL Index, Organic Brain Syndrome (OBS) Scale [146], Life Orientation Scale [147], ADL Staircase, and PGCMS [145]. For participants with previously documented dementia diagnoses, these diagnoses were reviewed in light of the additional information collected. When previously undiagnosed dementia was suspected, participants' cognitive performance was interpreted in relation to clinical progression, educational level, sensory impairments, aphasia, functional decline, and relevant comorbidities, including depression, delirium, and stroke, as identified in medical records [148]. Final diagnoses of dementia were established according to the DSM-IV criteria [149].

Diagnosis of depressive disorders

Depressive disorders were assessed using a comprehensive evaluation approach similar to that applied for dementia. An experienced specialist in geriatric medicine evaluated the available information on all participants, including data from clinical assessments GDS-15, Life Orientation Scale [147], PGCMS, Montgomery-Åsberg Depression Rating Scale [150], OBS Scale [146], and MMSE), medical records, and medication prescriptions. This comprehensive review enabled the specialist to determine whether each participant met the DSM-IV criteria for a depressive disorder [25, 149].

Data analysis

In studies I-III, continuous variables were summarized as means with standard deviations or medians with interquartile ranges (IQRs), as appropriate, and categorical variables were summarized as frequencies and percentages. All statistical tests were two sided, and p values < 0.05 were considered to reflect significance. In Study IV, participants' ages were summarized using the median and the 25th and 75th percentiles (Q1-Q3).

Study I

The baseline characteristics of participants who did and did not sustain hip fractures during follow up were summarized descriptively. Analyses were also stratified by sex. The incidence rate of hip fracture was calculated as the number of hip fractures divided by the total person-years at risk and expressed per 1,000 person-years. Person-years were calculated from study inclusion until the first occurrence of hip fracture, death, or the end of the 5-year follow-up period, whichever occurred first.

Univariable Cox proportional-hazards regression analyses [151] were performed separately for women and men to examine associations between baseline characteristics and the time to hip fracture. Hazard ratios (HRs) with 95% confidence intervals (CIs) were estimated, and variables with p < 0.10 in univariable analyses were considered for inclusion in multivariable models. Separate multivariable Cox proportional-hazards models were fitted for women and men, with stratification by age group (85, 90, and ≥95 years) and allowance of variance in the baseline hazard function across age groups. MMSE scores were excluded because of their collinearity with dementia, and the "independence in transfer" variable was excluded because it is represented in the Barthel ADL Index. Correlations between variables included in the models were assessed using Pearson's and Spearman's coefficients; no coefficient exceeded 0.6. The proportional-hazard assumption was evaluated using Schoenfeld residuals [152].

Sensitivity analyses were performed to assess the robustness of the findings. The age group was first included as a categorical covariate, with the age of 85 years serving as the reference category, rather than as a stratification

variable. The primary models were additionally adjusted for rural/urban residence and residential care settings, and potential confounding by the available indicators of social circumstances was managed by additional adjustment for living alone and years of education. Fine-Gray competing-risk regression models [153] were applied to account for the competing risk of death before hip fracture. Hip fracture was defined as the event of interest, and death before hip fracture was defined as the competing event. Analyses were performed separately for women and men using the same covariates as in the Cox models. In these analyses, the Barthel ADL Index was modeled as a continuous variable to improve statistical stability. Subdistribution HRs with 95% CIs were estimated. Interaction terms between sex and each covariate were also tested to assess potential sex differences in associations.

The statistical analyses were performed using IBM SPSS Statistics version 28 (IBM Corporation, Armonk, NY, USA).

Study II

Analyses of 1-year mortality were conducted for participants who sustained hip fractures during the 5-year follow-up period. Categorical and continuous baseline characteristic variables were compared between participants who survived and those who died within 1 year after hip fracture. The survival time was defined as the interval from the date of hip fracture to the date of death or the end of the 1-year follow-up period.

Cox proportional-hazards regression was used to examine factors associated with 1-year mortality after hip fracture. HRs with 95% CIs were estimated. The multivariable model included factors selected a priori based on previous research and clinical relevance [154]: age group, fracture type, sex, residence in a residential care facility, cognitive status, heart failure, history of stroke, pre-fracture ADL, and BMI. The proportional-hazards assumption was evaluated by visual inspection of plots based on weighted Schoenfeld residuals [152, 155]. Correlations between variables were assessed using Pearson's and Spearman's coefficients; no coefficient exceeding 0.6 was identified. Kaplan-Meier survival analyses [156] were used

to visualize survival according to factors associated significantly with mortality in the multivariable Cox model.

The statistical analyses were performed using IBM SPSS Statistics version 28 (IBM Corporation).

Study III

Baseline characteristics were compared between participants who survived and those who died within 36 months after hip fracture. Pearson's chi-squared test and Fisher's exact test were used for the assessment of categorical variables. Normally and non-normally distributed data were compared using the independent-samples *t* test and Mann-Whitney *U* test, respectively. Correlations between baseline variables were assessed using Pearson's and Spearman's coefficients; no coefficient exceeding 0.6 was identified.

Univariable analyses were performed to examine associations between baseline characteristics and mortality at 12, 24, and 36 months. Variables associated with mortality at $p \leq 0.10$ in the univariable analyses were considered for inclusion in multivariable logistic regression models. Multivariable logistic regression analyses were performed using a conditional forward stepwise method to examine factors associated with mortality at 12, 24, and 36 months after hip fracture [157]. Odds ratios with 95% CIs were estimated. Associations of depressive disorders and dementia with mortality at each follow-up time point were examined separately and in combination.

The statistical analyses were performed using IBM SPSS Statistics version 25 (IBM Corporation).

Study IV

Reflexive thematic analysis was applied to the qualitative data, as described by Braun and Clarke [158, 159], in combination with a longitudinal thematic approach [113]. The analysis was predominantly inductive, with the ICF used as a deductive framework during initial coding and the early stages of theme development. The ICF conceptualizes functioning and disability in

relation to body functions and structures, activities, participation, and contextual factors [124]. As the analysis progressed, the themes were developed inductively from the participants' accounts, rather than imposing a restriction to the ICF framework.

The analysis was iterative and reflexive, with two stages and six phases (Figure 3). In stage 1 (phases 1-3), the complete dataset, comprising interviews from all three time points, was analyzed to develop an overall understanding of participants' experience of recovery. In phase 1 (familiarization), the author repeatedly read all transcripts and noted initial reflections. In phase 2 (generating initial codes), the author coded relevant interview segments using a low-inference approach, with codes kept close to participants' accounts. In phase 3 (searching for themes), the research team collaboratively grouped the initial codes into potential themes, guided deductively by the ICF domains. These potential themes were subsequently developed inductively through continued engagement with the coded data and the complete dataset.

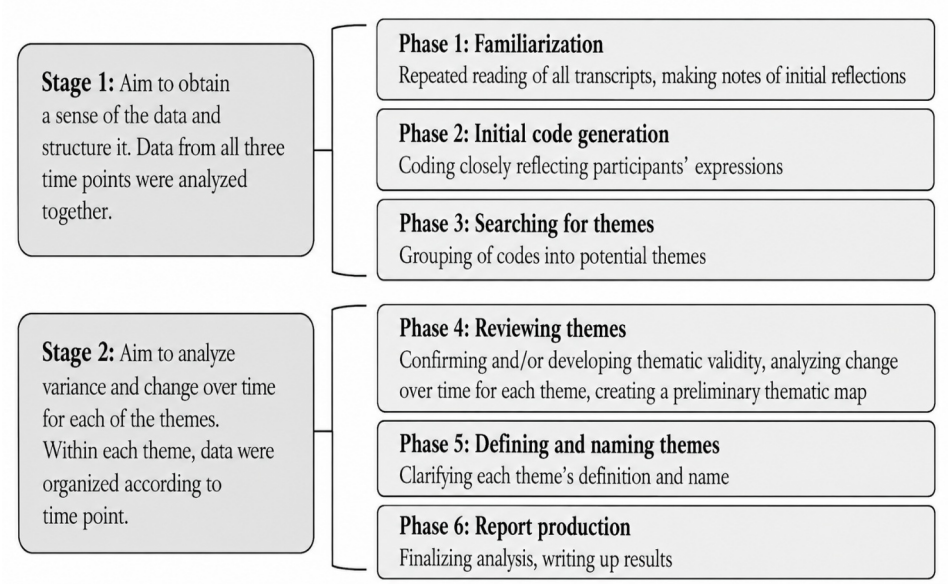


Figure 3. *Overview of the two-stage analytical process applied in study IV, based on Braun and Clarke's [160, 161] six phases of reflexive thematic analysis and the principles of longitudinal qualitative analysis.*

In stage 2 (phases 4-6), the longitudinal dimension of recovery was explored by examining continuity and change within the themes across the three interview time points. In phase 4 (reviewing themes), the author and a fellow researcher reviewed the codes and underlying data and refined the themes, including the merging or redefining of themes to better represent the data. Data within each theme were then organized according to the three interview time points, enabling the examination of patterns of continuity and change in participants' recovery experiences across the first year after fracture. In phase 5 (defining and naming themes), the research team collaboratively defined and named the themes. Phase 6 (producing the report) involved the finalization of the analysis and writing up of the findings, with contributions from all research team members.

Reflexivity was maintained through the analytical process through ongoing discussions within the research team. The team brought complementary clinical and methodological expertise, including backgrounds in orthopedic surgery, nursing, physiotherapy, and longitudinal qualitative research. Throughout the analysis, the team reflected on how these different perspectives could influence the interpretation of participants' accounts [159]. Data were coded using MAXQDA (version 22.7.0; VERBI Software, Berlin, Germany).

Results

Sex-specific associations of factors with hip fracture in very old adults

In study I, 18.6% of the 1,277 participants had previous hip fractures, and this characteristic was more common among women than among men (22.4% vs. 11.7%). During the 5-year follow-up period, 184 (14.3%) participants sustained hip fractures, corresponding to an overall incidence rate of 45.7 per 1,000 person years. The incidence was similar in women and men (Table 3).

Table 3. *Selected baseline characteristics of participants with and without hip fracture.*

Characteristic	Men			Women			Total	
	No hip fracture during follow-up (n = 373)	Hip fracture during follow-up (n = 64)	Unadjusted HR (95% CI)	No hip fracture during follow-up (n = 720)	Hip fracture during follow-up (n = 120)	Unadjusted HR (95% CI)	No hip fracture during follow-up (n = 1093)	Hip fracture during follow-up (n = 184)
Sociodemographic factors								
Age	88.6 (4.4)	88.5 (3.9)	0.99 (0.94–1.06)	89.8 (4.9)	89.3 (4.4)	0.99 (0.95–1.02)	89.4 (4.8)	89.0 (4.2)
Living in residential care facility	103 (27.6)	18 (28.1)	1.05 (0.61–1.81)	297 (41.3)	38 (31.7)	0.71 (0.48–1.04)	400 (36.6)	56 (30.4)
Living alone	215 (57.6)	33 (51.6)	0.79 (0.48–1.29)	623 (86.5)	104 (86.7)	1.01 (0.60–1.72)	838 (76.7)	137 (74.5)
Use of a walking aid	249 (67.7)	41 (65.1)	0.96 (0.57–1.61)	583 (82.9)	83 (70.3)	0.55 (0.37–0.82)	832 (77.7)	124 (68.5)
Independence in transfer	332 (89.7)	63 (98.4)	6.63 (0.92–47.78)	569 (79.6)	110 (92.4)	2.89 (1.47–5.71)	901 (83.0)	173 (94.5)
Current smoker	13 (3.5)	4 (6.3)	1.74 (0.60–5.02)	12 (1.7)	8 (6.9)	3.56 (1.72–7.32)	25 (2.3)	12 (6.7)
Alcohol use	212 (59.2)	30 (48.4)	0.66 (0.40–1.08)	250 (36.0)	56 (48.7)	1.59 (1.10–2.29)	464 (43.9)	86 (48.6)
Medical diagnoses and conditions								
History of hip fracture	46 (12.3)	5 (7.8)	0.64 (0.26–1.60)	168 (23.3)	20 (16.7)	0.70 (0.43–1.13)	214 (19.6)	25 (13.6)
History of fall in previous year	170 (46.6)	35 (55.6)	1.43 (0.87–2.35)	320 (46.6)	58 (49.2)	1.12 (0.78–1.60)	490 (46.6)	93 (51.4)
Hip prosthesis	40 (10.9)	2 (3.2)	0.29 (0.07–1.20)	92 (13.0)	6 (5.0)	0.37 (0.16–0.85)	132 (12.3)	8 (4.4)
Parkinson's disease	2 (0.5)	2 (3.1)	5.09 (1.24–20.82)	7 (1.0)	2 (1.7)	1.83 (0.45–7.42)	9 (0.8)	4 (2.2)
Dementia	111 (29.8)	16 (25.0)	0.83 (0.47–1.46)	287 (39.9)	31 (25.8)	0.57 (0.38–0.86)	398 (36.4)	47 (25.5)
Dementia but no depressive disorder	57 (15.3)	7 (10.9)	0.71 (0.32–1.55)	131 (18.2)	10 (8.3)	0.44 (0.23–0.84)	188 (17.2)	17 (9.2)
Depressive disorder	108 (29.0)	16 (25.0)	0.85 (0.48–1.50)	278 (38.8)	45 (37.5)	0.97 (0.67–1.40)	286 (35.4)	61 (33.2)
Depressive disorder but no dementia	54 (14.5)	7 (10.9)	0.75 (0.34–1.63)	124 (17.2)	34 (20.0)	1.18 (0.75–1.84)	178 (16.3)	31 (16.8)
Dementia and depressive disorder	54 (14.5)	8 (12.7)	0.90 (0.43–1.89)	154 (21.5)	21 (17.5)	0.81 (0.51–1.30)	208 (19.1)	29 (15.8)

Data are presented as n (%) unless otherwise stated; age is presented as mean (SD). HR = hazard ratio; CI = confidence interval.

At baseline, most participants lived in their own homes and were independent in transfers, often with the use of a walking aid. Depressive disorders were the most common medical condition, particularly among women, and dementia was present in approximately one-quarter of men and women (Figure 4).

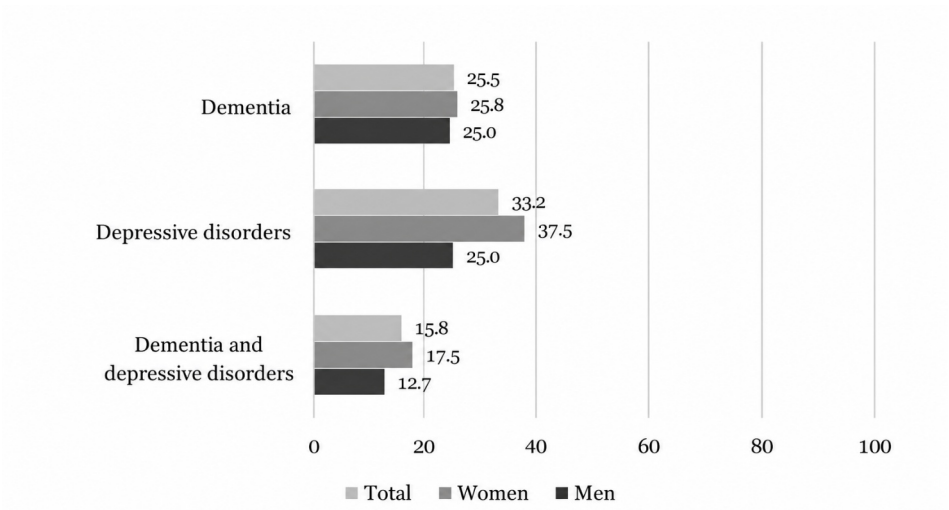


Figure 4. *Pre-fracture prevalence (%) of dementia, depressive disorders, and both among very old adults who sustained hip fractures during follow up (n = 184).*

The hip fracture incidence varied across levels of functional independence; it was lower among the most dependent individuals and higher among those with more independence (Figure 5). The highest incidence was observed among individuals with Barthel ADL Index scores of 9-16.

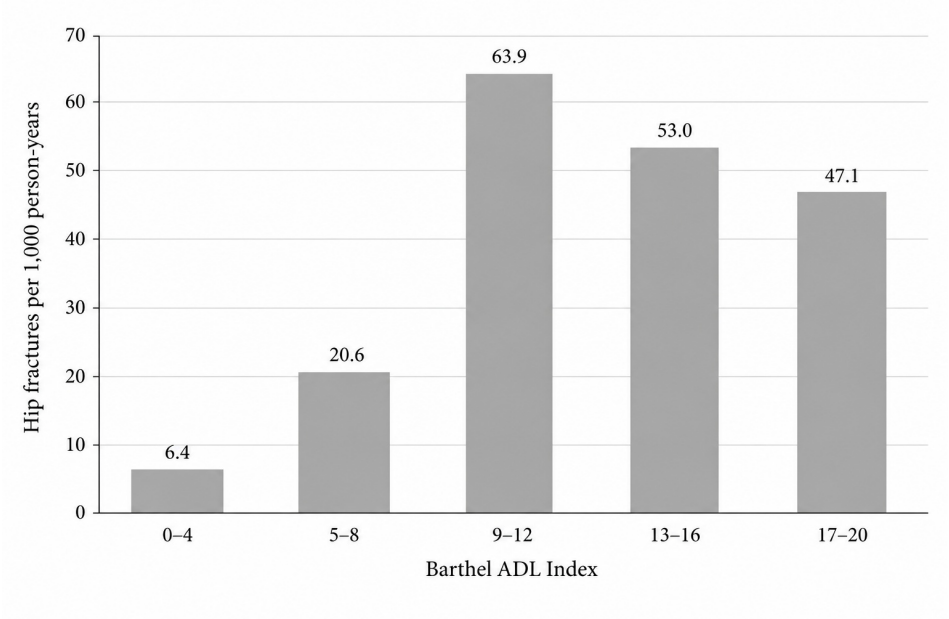


Figure 5. *Hip fracture incidence rates across levels of functional independence. ADL, activities of daily living.*

In sex-stratified analyses, more factors were associated with hip fracture among women than among men. Among women, current smoking and greater functional independence were associated with an increased fracture risk, whereas the use of a walking aid and having a hip prosthesis were associated with a lower risk (Table 4).

Table 4. *Factors associated with hip fracture among women, determined by multivariable Cox proportional-hazards regression.*

Women	HR	95% CI	*P*
Living in residential care facility	1.56	0.92-2.65	0.101
Use of a walking aid	**0.61**	**0.39-0.95**	**0.030**
Current smoker	**4.94**	**2.30-10.57**	**<0.001**
Alcohol use	1.25	0.84-1.86	0.267
Hip prosthesis	**0.30**	**0.12-0.76**	**0.011**
Hearing impairment	0.57	0.29-1.13	0.108
Barthel ADL Index score	**1.12**	**1.04-1.21**	**0.004**
Dementia	0.99	0.58-1.70	0.968
Mini Nutritional Assessment score	0.95	0.88-1.01	0.098

HR, hazard ratio; CI, confidence interval; ADL, activities of daily living

Among men, fewer factors were identified. Parkinson's disease was associated with a substantially higher fracture risk, and alcohol use was associated with a lower risk (Table 5).

Table 5. *Factors associated with hip fracture among men, determined by multivariable Cox proportional-hazards regression.*

Men	HR	95% CI	*P*
Alcohol use	**0.27**	**0.13-0.53**	**<0.001**
Parkinson's disease	**24.77**	**2.01-203.87**	**0.003**
Hip prosthesis	0.22	0.03-1.58	0.131
Heart failure	0.60	0.14-2.52	0.486
Gait speed	2.45	0.86-7.04	0.095
Barthel ADL Index score	1.08	0.86-1.35	0.505
Analgesic use	0.94	0.48-1.83	0.743

HR, hazard ratio; CI, confidence interval; ADL, activities of daily living

Overall, the findings demonstrate that risk factors for hip fracture differ between men and women in very old age. Among women, greater functional independence was associated with an increased fracture risk.

Factors associated with the 1-year mortality risk after hip fracture among very old adults

In study II, the rate of mortality in the first year after hip fracture was 47.8%. Among those who died within the first year, the median time from hip fracture to death was 61 days (IQR 149), corresponding to 61 days (IQR 138) among women and 48 days (IQR 162) among men.

Several factors were associated independently with increased 1-year mortality (Table 6). Depressive disorders and a history of stroke were significant predictors. The fracture type was associated with mortality, with subtrochanteric fractures linked to a higher risk of death. In contrast, overweight/obesity was associated with a lower mortality risk. Chronological age was not associated significantly with mortality in the adjusted model.

Table 6. *Factors associated with mortality in the year after hip fracture, determined by multivariable Cox proportional-hazards regression.*

	HR	95% CI	*P*
Age group (years)			
85	Ref.		
90	0.64	0.33-1.17	0.145
≥95	1.06	0.54-2.08	0.875
Women	0.66	0.37-1.15	0.143
Fracture type*			
Femoral neck fracture	Ref.		
Trochanteric fracture	1.18	0.69-2.04	0.543
Subtrochanteric fracture	**4.40**	**1.73-11.21**	**0.002**
Living in residential care facility	1.77	0.97-3.22	0.062
Dementia but no depressive disorder	1.89	0.73-4.92	0.193
Depressive disorder but no dementia	**2.55**	**1.32-4.93**	**0.005**
Dementia and depressive disorder	0.92	0.42-2.03	0.840
Heart failure	2.13	0.84-5.42	0.114
History of stroke	**2.34**	**1.17-4.66**	**0.016**
Malignancy in the previous 5 years	1.84	0.94-3.58	0.075
Barthel ADL Index score	1.02	0.92-1.13	0.696
BMI category (kg/m²)			
Normal weight (22-29)	Ref.		
Obese (≥30)	**0.26**	**0.10-0.67**	**0.005**
Underweight (<22)	1.28	0.64-2.55	0.484

** Fracture type data were missing for six participants.*
HR, hazard ratio; CI, confidence interval; ADL, activities of daily living; BMI, body mass index

Overall, the findings demonstrate that mortality after hip fracture in very old adults is substantial but not uniform, and that it is associated more strongly with the pre-fracture health status and vulnerability than with chronological age.

Dementia and depressive disorders in relation to the mortality risk at 12, 24, and 36 months after hip fracture

In study III, the mean age of the 404 participants was 82.6 ± 6.5 years, and 73% of participants were women. Of all participants, 38.5% had depressive disorders, 41.3% had dementia, and 23.3% had both conditions.

Dementia was consistently associated with increased mortality at 12, 24, and 36 months following hip fracture, both among individuals with dementia alone and among those with coexisting depressive disorders. In contrast, depressive disorders alone were not associated with a significant increase in mortality risk at any of the follow-up time points. The combination of dementia and depressive disorders was associated with numerically higher odds ratios than dementia alone at all three follow-up time points (Figure 6).

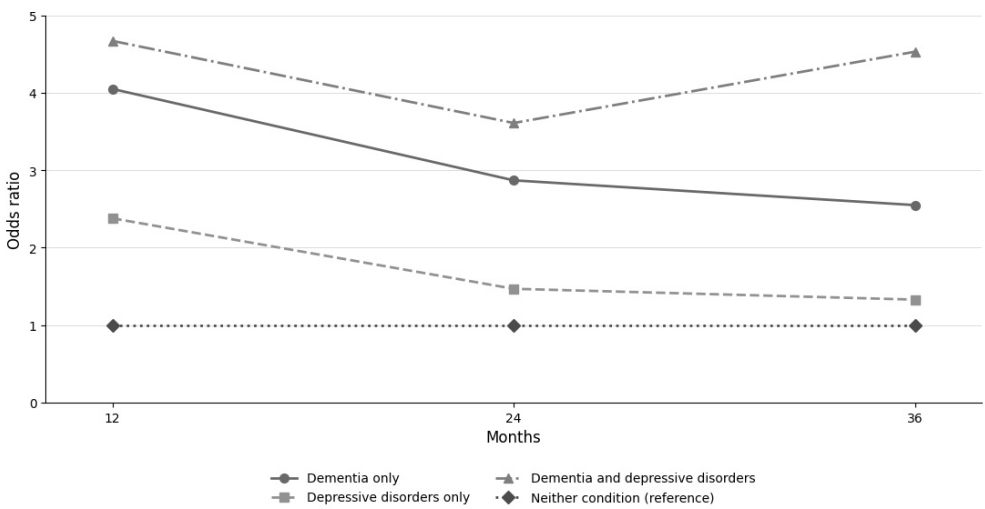


Figure 6. *Adjusted odds ratios for mortality at 12, 24, and 36 months after hip fracture according to dementia and depressive disorder statuses.*

Overall, the findings indicate that dementia is a stable predictor of mortality over time, whereas the influence of depressive disorders is more variable. The results suggest that the relationship between these conditions combined and mortality is complex and does not follow a simple additive pattern.

Older adults' experience of recovery during the first year after femoral neck fracture

In study IV, participants had a median age of 79 (Q1-Q3: 77-84) years, and the majority (69%) of participants were women. All participants were able to return to their pre-fracture residences after hospital discharge.

The participants described recovery after femoral neck fracture as a complex and non-linear process, rather than a steady progression toward improvement. They experienced recovery as fluctuating over time, with periods of progress interspersed with stagnation and setbacks.

Four interrelated themes representing key aspects of recovery were identified: engagement in daily activities, fear of falling, family members' bridging of the support gap, and striving for independence (Figure 7). Recovery unfolded through interplay among physical, emotional, and social dimensions, the importance of which changed throughout the first year.

Figure 7. *Themes describing key aspects of recovery during the first year after hip fracture. (AI generated image)*

Engagement in daily activities was characterized by an initial focus on managing physical limitations, including pain, fatigue, reduced mobility, and difficulty performing everyday activities. Over time, the focus gradually shifted toward adaption and reconnection with routines and meaningful activities. At 4 months, recovery trajectories had become increasingly diverse; whereas some participants experienced reduced pain, improved mobility, and greater independence, others continued to experience pain, fatigue, and limitations on social participation. At 1 year, all participants had resumed daily activities to some extent, and most felt that they had returned to their pre-fracture selves. However, some continued to experience fatigue,

anxiety, physical limitations, and/or the loss of previously valued social activities.

Participants' **fear of falling** influenced their mobility, participation, and everyday decision making throughout recovery. Although the nature and intensity of this fear changed over time, improved physical function did not necessarily restore confidence. Some participants continued to restrict their activities despite physical improvement, illustrating how psychological recovery did not always progress in parallel with physical recovery.

Family members' bridging of the support gap was particularly important following participants' discharge from the hospital. Participants described receiving limited formal support after they had returned home; family members provided practical assistance with everyday tasks and, in some cases, personal care. Although this support facilitated participants' ability to remain at home, becoming dependent on family members could also evoke feelings of guilt, role reversal, and concern about being a burden. As participants became more independent, the role of family members shifted gradually from primarily practical assistance toward encouragement, motivation, and emotional support.

Striving for independence remained central throughout the first year after hip fracture, although motivation and persistence varied among participants. Many described recovery as requiring personal responsibility and perseverance. Optimism, curiosity, and resilience supported some participants in remaining active, whereas others experienced fatigue, apathy, or uncertainty about achievable goals. Participants consistently perceived physical exercise as important, and noted that their motivation was supported by both their internal drive and encouragement from family members, friends, physiotherapists, and other resources. For some participants, the fractures also prompted reflection and meaning making, including renewed appreciation of life and future goals, whereas others experienced the fracture more as a turning point associated with aging and loss.

Overall, the participants experienced recovery after hip fracture as a dynamic and individualized process, rather than a linear return to their pre-

fracture function. Their physical improvement was intertwined with the regaining of confidence, meaningful activities, social connection, and a sense of independence and continuity in everyday life.

Discussion

The findings of this thesis suggest that hip fracture in later life should be understood as a complex and life-altering event that occurs along an ongoing health trajectory, rather than solely as an isolated orthopedic injury or an inevitable consequence of aging. Here, the findings of the four studies are integrated by discussing them in relation to three interrelated dimensions, which were not predefined: **exposure**, **vulnerability**, and **recovery**. In this synthesis, exposure refers to the circumstances under which a hip fracture may occur, including opportunities for fall-related situations; vulnerability refers to an individual's susceptibility to withstand the consequences of a hip fracture; and recovery refers to the process of adapting and rebuilding everyday life following the event.

The dimension of **exposure** is illustrated in study I, the results of which suggested that functional independence influenced the circumstances under which a hip fracture risk was present. Although the incidence of hip fracture among very old women and men was similar, the factors associated with hip fracture differed between the sexes. Among women, greater independence in ADL was associated with an increased risk of hip fracture. This finding suggests that risk may reflect not only frailty or impaired function, but also exposure to situations in which falls can occur.

Vulnerability was particularly evident in studies II and III. Nearly half of the very old adults in study II died within 1 year of hip fracture, although chronological age was not associated independently with mortality. Instead, mortality was associated with depressive disorders, previous stroke, and subtrochanteric fracture, whereas obesity was associated with a lower mortality rate. Study III further showed that dementia and depressive disorders were associated with different patterns of mortality over time. Their coexistence did not produce a simple additive increase in the mortality risk, indicating that vulnerability cannot be understood solely as the accumulation of individual risk factors.

Study IV illustrates **recovery** as a non-linear and adaptive process. Recovery was shaped not only by changes in physical function, but also by

participants' fear of falling, ability to manage everyday activities, receipt of support from family members, pursuit of independence, and access to rehabilitation and healthcare support. These findings demonstrate that recovery extends beyond biological healing and develops through interaction among individual capacity, emotional responses, social relationships, and the surrounding care context.

Taken together, these findings support a multidimensional understanding of hip fracture in later life. The exposure, vulnerability, and recovery dimensions should not be understood as separate or determined by chronological age alone. Rather, they illustrate how hip fracture risk and outcomes are embedded within broader health and life trajectories. This perspective provides a foundation for more individualized and integrated approaches to hip fracture prevention, treatment, and recovery.

Exposure to the hip fracture risk and sex differences

The similar incidence of hip fracture among women and men in study I contrasts with the generally reported consistently higher incidence among women [160]. This finding should not be interpreted as evidence that established sex differences disappear in very old age. Individuals who survive into very old age constitute a selected group and may differ from the population from which they originated in terms of health, resilience, and previous risk exposure [161, 162]. Selective survival may thus contribute to changes in observed risk patterns at very old ages. However, whether this phenomenon explains the similar incidence among women and men could not be determined in the present research. The findings nevertheless suggest that similar incidence rates may coexist with different patterns of associated factors.

The association of greater independence in ADL with an increased hip fracture risk among women provides one example of how such pathways may operate. At first glance, this association may appear to be counterintuitive, as hip fracture is commonly associated with frailty, functional decline, and dependency [6, 101]. However, greater functional capacity may enable continued engagement in everyday activities, thereby

creating more opportunities for exposure to situations in which falls may occur. Kelsey et al. [163] found that older adults who fell outdoors were generally healthier and more physically active than were those who fell indoors, illustrating that falls occur among people with different levels of health, mobility, and exposure.

Thus, the findings suggest that hip fracture may be reframed in terms of dynamic interaction between individuals' capacity and exposure, rather than a static marker of their frailty. Nevertheless, greater independence or activity should not be interpreted as inherently harmful. Physical activity has generally been associated with a lower risk of falling among older adults [164]. Functional independence, physical activity, and exposure to fall-related situations are thus related but distinct concepts. The measure of independence used in study I did not capture how frequently, where, or under what circumstances participants were physically active. The association should consequently be understood as a possible indication of exposure, rather than evidence that independence itself increases the hip fracture risk.

The sex-specific associations identified in study I further suggest that the similar hip fracture incidence among women and men arises though the existence of partially differing constellations of risk. Some associations, such as those with smoking among women and Parkinson´s disease among men, are consistent with known fracture risk pathways involving bone health, balance, and mobility [26, 165-167]. Other associations, including those with alcohol use, walking aid use, and the previous presence of a hip prosthesis, are more difficult to interpret. These variables may reflect differences in health, behavior, mobility, healthcare contact, or adaptation to an already recognized fall risk, rather than directly protective or harmful effects. The binary assessment of alcohol use and limited number of events in the sex-specific analyses also warrant particular caution. Taken together, these findings support an understanding of the hip fracture risk as arising from interacting biological, functional, behavioral, and contextual factors, rather than from single characteristics considered in isolation.

Vulnerability and survival after hip fracture

Mortality following hip fracture was high in this work, but was not associated independently with chronological age in adjusted analyses. Instead, it was associated with specific aspects of health and the fracture events, including depressive disorders, previous stroke, and subtrochanteric fractures.

These findings challenge the common reliance on age as an explanatory factor. Although age is a strong population-level marker of mortality after hip fracture [50, 168], it may partly reflect the accumulation of disease, functional decline, and reduced physiological reserve, rather than constituting a sufficient explanation in itself. The interpretation of the mortality risk based on age alone may thus obscure clinically relevant differences among individuals of the same chronological age.

A history of stroke may indicate underlying neurological and functional vulnerability that reduces the capacity to withstand the additional stress of a hip fracture. The observed association of this variable with mortality is consistent with previous evidence of high short-term mortality rates among patients with stroke histories and hip fractures [169]. Similarly, the increased mortality associated with subtrochanteric fractures may be related to the greater clinical burden of this fracture type, including more blood loss and more frequent restrictions on postoperative weight bearing [170]. These findings illustrate that survival is shaped not only by a person´s pre-fracture health, but also by the characteristics of the fracture and its treatment. Hip fracture should thus be understood as a critical event occurring along an existing health trajectory, rather than as an isolated injury.

Obesity was associated with a lower mortality rate in study II. Similar findings have been reported after hip fracture and have sometimes been described as representing the obesity paradox [171]. However, this association should not be interpreted as evidence that obesity is protective. The BMI does not distinguish between fat mass and muscle mass, and thus may inadequately reflect very old adults' body composition and muscle-related vulnerability [172]. Moreover, survival bias may contribute to the apparent survival advantage associated with obesity after hip fracture [173].

The finding instead underscores the limitations of interpreting single risk indicators without considering the broader clinical context.

The results of this work align with previous findings demonstrating that outcomes after hip fracture are shaped by comorbidity, functional status, and clinical complications, rather than age per se [80, 117, 174, 175]. Nevertheless, chronological age continues to structure how prognoses are interpreted in research and clinical practice. From an ageism-informed perspective, reliance on chronological age may contribute to assumptions of limited recovery or survival potential, thereby influencing clinical decision making, including judgements about the treatment intensity and rehabilitation potential [176, 177]. Such assumptions risk becoming self-reinforcing if less intensive care is provided on the basis of anticipated decline rather than an assessment of an individual's health, preferences, and potential to benefit.

Studies II and III further indicate that vulnerability after hip fracture is related to patients' cognitive and psychological health. Increased mortality was associated consistently with dementia and more variably with depressive disorders in study III, and the coexistence of dementia and depressive disorders did not increase the mortality risk in a simple additive manner. Vulnerability in later life may thus be better understood as dynamic and context dependent, rather than as the sum of separate diagnoses.

Several mechanisms may contribute to the mortality associated with dementia and depressive disorders, including increased risks of delirium, malnutrition, reduced mobility, postoperative complications, and difficulty participating in rehabilitation [49, 178, 179]. Previous research has shown that rehabilitation participation may mediate the association between depressive symptoms, which may affect motivation and activity, and poorer functional recovery after hip fracture [180, 181]. However, these mechanisms are unlikely to operate uniformly across individuals or remain constant throughout the years following a hip fracture. The changing associations observed in study III may reflect shifts in participants' perceptions of the relative importance of their acute fracture events, underlying disease, rehabilitation, and subsequent health changes over time.

Although the mechanism explaining these temporal patterns could not be identified in the study, the findings serve as a warning against the treatment of vulnerability as a fixed characteristic established at the time of fracture.

The interpretation of these findings solely from a biomedical perspective may also lead to the oversimplification of how vulnerability is produced and maintained. Dementia and depressive disorders may influence participation and recovery through their clinical manifestations. However, these diagnoses may also shape how individuals' recovery potential is interpreted in healthcare. Healthcare professionals may have difficulty assessing the recovery potential of people with dementia and hip fracture, and standard rehabilitation approaches may need to be adapted to individuals' cognitive needs [182]. More broadly, healthcare professionals' attitudes toward aging may influence their expectations of older adults' capacity to participate in and benefit from care and rehabilitation [177], despite evidence that they can benefit from appropriately adapted and structured rehabilitation [183-185]. When cognitive impairment or depression results in less active treatment, reduced rehabilitation intensity, or fewer opportunities to participate in decision making, clinically recognized vulnerability may be compounded by the organization and delivery of care.

Depressive disorders warrant particular attention because they are often underrecognized in older adults. Their symptoms may overlap with manifestations of physical illness or cognitive impairment, and may also be interpreted as an expected part of aging, rather than as signs of a potentially treatable condition [186, 187]. Such interpretations may reflect broader ageist assumptions that withdrawal, passivity, and/or emotional distress are inevitable in later life. The failure to identify and address depression may, in turn, reduce an individual's participation in rehabilitation and limit their ability to regain everyday function [181, 188]. The associations of depressive disorders with mortality in studies II and III thus support the importance of including psychological health in assessments and follow up after hip fracture, rather than regarding it as secondary to physical recovery.

In summary, these findings support a shift from the imposition of labels based on individuals' chronological age and diagnoses toward a

multidimensional assessment of vulnerability. Nurses have a central role in the implementation of this shift through their continuous assessment, early recognition of deterioration, identification of cognitive and depressive symptoms, and advocacy for care that reflects individuals' needs and goals. Such an approach may help to ensure that treatment and rehabilitation decisions are based on clinical vulnerability and the potential to benefit, rather than on assumptions associated with patients' age or diagnoses.

Recovery as a lived and dynamic process

Although mortality is an important outcome, recovery after hip fracture cannot be reduced to survival or the restoration of physical function. The findings of study IV suggest that recovery is experienced as a dynamic, non-linear, and ongoing process, shaped by the interplay among bodily changes, emotional responses, social relationships, and the conditions of everyday life.

Participants described periods of progress, stagnation, and setbacks throughout the first year after hip fracture. This pattern challenges perspectives in which recovery is understood primarily as a linear trajectory toward restored function within a predefined timeframe. Instead, recovery may be understood as a continuing process of adaption, in which older adults negotiate independence, dependence, and continuity in everyday life in relation to changing bodily capacities [11, 20, 95, 97, 189].

The fear of falling emerged as a persistent dimension of recovery that influenced participants' mobility, participation, and decision making about everyday activities. Its persistence despite improvements in physical function suggests that functional recovery does not necessarily restore confidence or a sense of safety. Fear may contribute to activity restriction, thereby limiting opportunities to regain function and resume meaningful aspects of everyday life [20, 190]. An understanding of recovery thus needs to encompass not only individuals' physical capacity, but also their confidence, perceived safety, and participation.

The findings further illustrate that recovery is relational, rather than solely individual. Family members enabled participants to manage everyday

activities and maintain continuity during recovery, sometimes compensating for gaps in formal care. At the same time, the receipt of help may create tension between the need for support and the desire to remain independent, accompanied by feelings of guilt or concern about becoming a burden. Thus, family support may both facilitate recovery and shape how individuals experience dependence, autonomy, and progress [95, 191].

Reliance on family members may also reflect gaps in continuity and coordination along the recovery pathway. After hospital discharge, the needs of older adults with hip fracture may change and extend beyond physical rehabilitation to include wound-related concerns, emotional distress, fall-related fear, and practical difficulties in everyday life. Previous research has similarly described fragmented care, unclear responsibilities, and difficulty with the navigation of services after hip fracture [192, 193]. These findings suggest a need for accessible and continuous professional support, with the ability to identify emerging concerns and guide individuals toward appropriate services throughout the recovery period. The support that individuals require during recovery may also be shaped by their cognitive impairment, depressive disorders, and/or other pre-existing vulnerabilities. These conditions should not be interpreted as indicating a lack of recovery potential, but may necessitate the adaptation of rehabilitation and communication to individuals' needs.

Ageism as an analytical lens in hip fracture care

Ageism was not directly examined or applied as a theoretical framework in the studies performed for this thesis. However, several findings challenge the validity of simplified assumptions about aging and older adults. The association of greater functional independence with the hip fracture risk among very old adults; the association of mortality with clinical and psychological factors beyond chronological age; and the characterization of recovery as involving individual and changing experiences of independence, dependence, and support highlight substantial heterogeneity among older adults with hip fracture and raise questions about the extent to which chronological age and age-related assumptions adequately capture their risks, needs, and recovery potential. Ageism is thus used here as an

analytical lens to further interpret the findings and consider their implications for hip fracture care.

Butler [194] introduced the concept of ageism to describe prejudice and discrimination directed toward older people. The concept has since been broadened to encompass stereotypes, prejudice, and discrimination based on age [16]. Ageism may operate at self-directed, interpersonal, and institutional levels, influencing how older adults are represented, are treated by others, and understand their own aging [16]. These levels provide a structure for the consideration of how age-related assumptions may shape healthcare priorities, interactions with healthcare professionals and family members, and older adults' interpretations of dependence and recovery after hip fracture.

At the self-directed level, ageism may be reflected in internalized assumptions about aging, independence, and dependency. Older adults may interpret functional decline or the need for support as an expected or undesirable consequence of aging, which may influence how they perceive their own capacity and recovery [16, 195]. In study IV, participants described concern about being dependent on others, guilt, and the desire to regain independence. Although these experiences cannot in themselves be interpreted as evidence of self-directed ageism, an ageism-informed lens draws attention to how cultural ideals of independence may affect the meaning attached to receiving help in later life.

At the interpersonal level, assumptions about aging may influence interactions among older adults, family members, and healthcare professionals. Expectations regarding what an older person can or should be able to achieve after hip fracture may shape communication, encouragement, and opportunities for participation in rehabilitation. Previous research suggests that healthcare professionals' attitudes toward aging influence their expectations of older adults' capacities and care needs [177]. Such assumptions may be particularly consequential for people with cognitive impairment or depressive disorders, whose rehabilitation potential may be underestimated when their vulnerability is interpreted as an indication of a limited capacity for recovery, despite evidence that cognitive

impairment does not preclude individuals from benefitting from appropriately adapted rehabilitation [184].

At the institutional level, ageism may be reflected in healthcare systems' organization of assessment, treatment, rehabilitation, and follow up for older adults [16, 176, 196]. In hip fracture care, standardized pathways may insufficiently accommodate differences in patients' pre-fracture function, cognitive and emotional vulnerability, social circumstances, and recovery goals. Chronological age may become an implicit marker of expected benefit or rehabilitation potential, despite considerable heterogeneity in health, function, cognition, and social circumstances among older adults. The findings of this thesis emphasize the importance of recognizing this heterogeneity, rather than treating older adults with hip fractures as a homogeneous group.

An ageism-informed perspective may also contribute to the understanding of the study I findings on the hip fracture risk. An emphasis on decline, frailty, and dependency in very old age may obscure individuals' retention of functional capacity and continued participation in everyday life. The viewing of very old adults as uniformly frail or inactive may thus lead to the overlooking not only of individual capacity, but also differences in exposure to situations in which falls may occur. The association of greater functional independence with the hip fracture risk in study I illustrates the importance of considering older adults' health, functional capacity, activity, and environmental exposure, rather than relying on chronological age or assumed frailty when assessing their fracture risk.

An ageism-informed perspective also raises questions about how recovery is defined and evaluated. When mobility and independence are treated as the principal indicators of successful recovery, psychological well-being, participation, perceived safety, autonomy, and continuity in everyday life may receive less attention [12]. The findings from study IV suggest that recovery involves more than the regaining of physical function and includes adaptation to changed circumstances, the rebuilding of confidence, and the regaining of control over meaningful aspects of everyday life. The broadening of our understanding of recovery may thus enable the

recognition of progress even when an individual does not return completely to the pre-fracture level of function.

This perspective is also consistent with the United Nations' 2030 Agenda for Sustainable Development, particularly Sustainable Development Goal 3, which aims to ensure health and well-being for people of all ages, and Sustainable Development Goal 10, which aims to reduce inequalities [197]. The addressing of age-based assumptions and promotion of equitable access to treatment, rehabilitation, and support may contribute to the broader commitment to leave no one behind [197].

Taken together, the application of an ageism-informed lens to the findings highlights the importance of avoiding assumptions based primarily on chronological age, dependency, or diagnoses. Instead, hip fracture care should recognize heterogeneity in exposure, vulnerability, and recovery and support assessment and rehabilitation based on individuals' health, functional capacity, psychological and cognitive resources, social context, and personally meaningful goals.

Methodological considerations

The investigation of the research questions posed in this thesis required the application of different methodological approaches. Quantitative methods were used in studies I-III to examine factors associated with hip fracture and mortality, whereas a longitudinal qualitative approach was used in study IV to explore older adults' experiences of recovery over time. These complementary methodological approaches enabled the examination of different dimensions of hip fracture in later life, ranging from measurable health outcomes and associated factors to individual experiences of recovery.

Trustworthiness and pre-understanding

Trustworthiness in qualitative research concerns the credibility, transferability, dependability, and confirmability of the research process and findings [198]. Researcher reflexivity is important in this regard, as researchers' backgrounds, experiences, and pre-understanding may

influence decisions throughout the research process, including during data collection, analysis, and interpretation [199]. The research team represented diverse clinical and research backgrounds, including expertise in orthopedics and geriatrics and professional backgrounds in medicine, physiotherapy, and nursing. Differences in clinical experience, methodological expertise, age, and gender contributed to varying pre-understanding and perspectives within the team. This diversity provided opportunities to critically consider alternative interpretations throughout the research process [200]. In study IV, reflexive discussions within the research team contributed to the development of the themes and trustworthiness of the analysis [159]. Methodological expertise was further strengthened by the involvement of a researcher with specific experience in longitudinal qualitative research. Trustworthiness was also supported through prolonged engagement with the data and the application of an iterative analytical process in which themes were repeatedly considered in relation to the coded extracts and the complete dataset.

Pre-understanding is an inherent part of qualitative research that may influence how researchers approach and interpret data. It thus necessitates the use of a reflexive and self-critical approach throughout the research process [201]. Reflecting on my own pre-understanding, my perspective on older adults with hip fracture was initially shaped primarily by more than 10 years of clinical experience in an acute orthopedic ward. This experience provided extensive knowledge of the acute phase of hip fracture care, but limited insight into what recovery after hospital discharge entails. This clinical background inevitably influenced my pre-understanding of recovery and the outcomes I initially considered to be important. At the same time, my limited experience of patients' long-term recovery may have encouraged me to take an open and curious approach in study IV, allowing participants to describe aspects of recovery that extended beyond my clinical care-based perspective. Throughout the analysis, my interpretations were discussed with researchers representing different professional and methodological perspectives. These discussions provided opportunities to question assumptions derived from my clinical experience and to consider alternative interpretations of the participants' accounts.

Data sources, data collection, and sampling

Studies I-III involved secondary analyses of previously collected data. Although the use of existing data enables researchers to address new research questions efficiently, it limits their control over the variables considered and how they were measured, and relevant information may be unavailable or affected by missing data [202]. The systematic review and classification of radiographs strengthened fracture ascertainment and classification in studies I and II. I performed these steps using to the AO/OTA classification, and a co-author and senior consultant in orthopedic surgery then reviewed and verified the classifications. This procedure reduced reliance on a single assessor and may have reduced the risk of fracture misclassification [203].

Study III was performed with pooled individual-level data from two previously conducted RCTs. The pooling of data from different studies can increase the sample size and statistical power, and enable the researcher to address secondary research questions that they may not be able to examine sufficiently with data from a single study [204]. The data from the two RCTs were considered to be suitable for pooling because the trials were conducted at the same hospital, focused on hip fracture and subsequent rehabilitation and outcomes, and involved the application of largely comparable inclusion and exclusion criteria and assessment procedures. Despite this broad comparability, differences in eligibility criteria, fracture types, and study periods may have introduced some heterogeneity into the pooled sample [205].

Another strength of the present research was that the same experienced geriatrician clinically assessed the diagnoses of dementia and depressive disorders in studies I-III using comprehensive clinical information. This approach ensured the consistency of diagnostic assessment across the studies. However, reliance on a single clinician may also be considered a limitation, as no additional assessor independently evaluated the diagnoses. Consequently, inter-rater reliability could not be assessed, and the possibility of systematic bias in diagnostic judgement cannot be excluded [206].

The use of data from the GERDA study in studies I and II provided several methodological advantages. The comprehensive home-based assessments conducted in that study provided detailed individual-level information on medical conditions, functional ability, cognitive function, nutritional status, psychosocial factors, and lifestyle-related factors that may not be captured by routinely collected healthcare data [207]. Study III had a similar strength, as comprehensive assessments were conducted at the participants' residences. In studies I-III, assessments were complemented by medical record reviews, enabling the combined examination of detailed individual-level data and verified clinical information.

Furthermore, the performance of assessments in participants' homes and residential care facilities, together with the ability to obtain information from proxy respondents when needed, may have facilitated the inclusion of older adults with varying levels of health and functional ability (study I & II). This factor is particularly important when studying this population, as health limitations and transportation difficulties may constitute barriers to research participation [208], and the exclusion of individuals living in nursing homes or those requiring proxy respondents may lead to the underrepresentation of individuals with poorer health and greater functional limitations [208, 209]. Thus, the GERDA study design combined population-based sampling with comprehensive individual-level assessments while reducing some of the barriers to participation that are particularly relevant among very old adults.

Nevertheless, selection bias should be considered, particularly in studies I and II, as individuals who survive to very old age and participate in studies constitute a selected population. Thus, despite efforts to facilitate the participation of individuals with poorer health and functional limitations, non-participation and selective survival may still have influenced the composition of the study population [161, 209].

In study IV, the use of telephone interviews similarly reduced the need for participants to travel and may have facilitated the participation of older adults with functional limitations and those living farther away. Although telephone interviews do not provide access to visual and non-verbal cues

that can be perceived in face-to-face interviews, previous research suggests that they can generate qualitative data comparable to that obtained with face-to-face interviews [210]. Nevertheless, differences in interaction and depth between the two interview modes have been reported [211]. The sampling approach used in study IV also needs to be considered. Participants were recruited from a defined subgroup of HipSTHeR trial participants, and the Swedish language proficiency requirement led to the exclusion of individuals with other linguistic backgrounds. The implications of this sample selection factor for the transferability of the findings are discussed further below.

The study IV sample comprised 13 participants, which may have limited the breadth of experiences represented. However, the longitudinal design led to the capture of repeated, detailed accounts from each participant across three time points, providing substantial within-participant depth and enabling the exploration of changes and continuities in recovery over time. In longitudinal qualitative research, sample size definition requires the consideration of the volume and complexity of data generated through repeated interviews [212, 213]. Malterud et al. [214] introduced the concept of information power, suggesting that fewer participants are needed when a sample can provide more information relevant to the study aim. Information power is influenced by the specificity of the study aim and sample, the use of established theory, the quality of interview dialogue, and the analytical strategy. In study IV, the specificity of the study population and the performance of repeated interviews over the first year after hip fracture contributed to the information power of the sample, although the relatively small sample size may have limited the range of experiences captured.

Analyses

Different approaches to variable selection and model building were used across the quantitative studies. In studies I and III, the consideration of variables for inclusion in the multivariable analyses was based on the significance of associations in the univariable analyses. In study II, variables were selected a priori based on previous research and clinical relevance. In study III, a forward stepwise procedure was subsequently used to construct

the multivariable models. Data-driven variable selection procedures may cause model instability and increase the risk of overfitting, particularly when the number of outcome events is limited in relation to the number of variables considered [215]. This factor is particularly relevant with regard to study I, in which the performance of sex-specific analyses resulted in the occurrence of relatively few outcome events in some subgroups, and study III, in which stepwise variable selection was applied. The findings of these analyses should thus be interpreted with consideration of the number of outcome events and the potential uncertainty introduced by data-driven model building.

The statistical approaches used also differed according to the design and objectives of the quantitative studies. Cox proportional-hazards regression was used in studies I and II to analyze time-to-event outcomes, incorporating the occurrence and timing of events during follow up. In study III, multivariable logistic regression was used to examine mortality as a binary outcome at the predefined follow-up time points of 12, 24, and 36 months. This approach did not account for the timing of death within each follow-up period. The application of a time-to-event approach would have provided complementary information on mortality patterns over time.

Competing risk was particularly relevant in study I, given the advanced age of the study population and the 5-year follow-up period. Death precludes the subsequent occurrence of hip fracture, and conventional survival analyses may overestimate the probability of non-fatal outcomes when the competing risk of death is substantial [216]. To address this issue, Fine-Gray competing-risk regression was performed as a sensitivity analysis, with death treated as a competing event [153]. This approach provided an additional assessment of the robustness of the associations observed in the Cox regression analyses.

As studies I-III were observational with respect to the associations examined in this thesis, causal relationships for these associations could not be established. Although the multivariable regression models were adjusted for measured potential confounders, residual confounding from unmeasured or insufficiently measured factors cannot be excluded [217].

The findings should thus be interpreted primarily as associations, rather than causal effects.

The occurrence of relatively small numbers of outcome events in some subgroups, particularly among men and within specific diagnostic categories, may have reduced the statistical power and contributed to the imprecision of estimates, as reflected by wide CIs. Consequently, the absence of significant associations should not necessarily be interpreted as evidence of no association [218]. In addition, the examination of multiple associations across the quantitative studies increased the possibility of generating findings by chance. Individual significant results, particularly those derived from small subgroups or few events, should thus be interpreted cautiously and in relation to the overall pattern of findings.

The analysis performed in study IV had deductive and inductive elements. The ICF framework was used to structure the initial analysis, guiding the consideration of different dimensions of functioning and recovery. However, the use of a predefined framework may also have influenced which aspects of the participants' accounts were initially foregrounded. As the analysis progressed, theme development became more inductive, enabling the identification of patterns and experiences beyond the ICF framework.

The longitudinal design of study IV influenced the analytical process and the interpretation of the findings. Qualitative longitudinal analysis provides opportunities to examine continuity, change, and variation over time, but requires attention to patterns within individual trajectories and across participants [219]. Repeat interviewing at 1, 4, and 12 months enabled the consideration of participants' experiences across different phases of recovery, rather than as accounts reflecting single time points. This temporal perspective was particularly important for the characterization of recovery as a dynamic and non-linear process. At the same time, the integration of time and change into a qualitative longitudinal analysis is methodologically complex, as longitudinal data may be analyzed and presented with varying emphasis on chronological time, individual trajectories, and patterns of change [113].

Generalizability and transferability

Generalizability concerns the extent to which findings may be applicable beyond the population and setting in which they were generated [220]. It thus requires consideration of the study population characteristics, the study context, and the data collection period [221].

For studies I and II, the population-based GERDA study design and the inclusion of very old adults living in their own homes and in residential care facilities strengthen the relevance of the findings to very old adults in similar settings. However, the study population was restricted to adults aged 85 years and older in northern Sweden, and the findings may not be directly generalizable to younger populations of older adults or to populations in different healthcare and societal contexts. The repeated data collection covered an extended period of time, which can be considered both a strength and a limitation. The inclusion of data collected in several waves reduced the dependence of the findings on conditions specific to a single cohort or point in time. At the same time, changes in population health, preventive strategies, healthcare, and treatment over the study period may have affected the applicability of findings from earlier data collection waves to contemporary populations of very old adults.

The generalizability of the study III findings should similarly be considered in relation to the study's geographical and temporal context. The study was conducted at a single hospital in northern Sweden, whose healthcare organization, rehabilitation practices, and population characteristics may differ from those in other regions and countries. Furthermore, the data were collected more than a decade before study III was performed, and subsequent changes in hip fracture care and older population characteristics may limit the direct applicability of the findings to contemporary clinical settings. However, the multidisciplinary geriatrics-oriented approach underlying the original RCTs remains clinically relevant. Current national Swedish hip fracture care recommendations include primary patient management by an orthogeriatric team and the provision of care based on CGA [222]. Thus, although the temporal context of the study III data must be considered, central principles of the care model in place at the time of

data collection are consistent with current recommendations for Swedish hip fracture care.

For study IV, transferability rather than statistical generalizability is relevant. Transferability concerns the extent to which qualitative findings may have relevance beyond the specific study context, and it requires the reporting of sufficient information about the participants, setting, and context to allow readers to assess their applicability to other situations [221]. The study IV findings were generated with a specific group of older adults with femoral neck fracture in a Swedish healthcare context. The recovery experiences of the selected sample may thus not encompass the full range of experiences in the broader population of older adults with hip fractures, particularly those with other fracture types, different linguistic and/or cultural backgrounds, and/or more complex health and care needs. However, the longitudinal design enabled the capture of detailed accounts of recovery over the first year, enabling the identification of individual variation and common patterns in recovery experiences. Together with a detailed description of the study context and participants, this factor provides a basis for readers to assess whether the findings may be transferable to other older adults and healthcare contexts.

Ethical considerations

Older adults with hip fractures may experience vulnerability related to acute illness and injury, multimorbidity, cognitive impairment, functional limitations, and dependency on healthcare and support from others. Ethical considerations were thus particularly important throughout the research process. The potential burden associated with study participation was weighed against the expected value of generating knowledge that could contribute to the improved understanding of and care provision to this population [223].

In studies I-III, the assessors were attentive to participants' conditions during data collection and had the opportunity to consult the research teams when ethical concerns arose. When cognitive impairment affected participants' ability to understand study procedures or respond to requests to undertake them, relatives or caregivers could be consulted and provided with study information.

Data collection was conducted with respect for participants' autonomy and integrity. Assessments in studies I-III were sometimes carried out over several home visits, allowing for flexibility and minimizing the burden on participants. Participation was always voluntary, and data collection was discontinued when a participant showed any sign of discomfort or unwillingness to continue.

Studies I-III involved secondary analyses of previously collected data. These analyses were conducted within the scope of the relevant ethical approvals, without additional contact with the participants.

In study IV, informed consent was obtained verbally and in writing prior to participation. Given the longitudinal design and the time intervals between interviews, consent was reaffirmed before each interview, supporting continued voluntary participation throughout the study period. The interviews potentially involved the discussion of sensitive experiences related to hip fracture and recovery. Participants were given the opportunity to pause or discontinue an interview at any time, and the interviewer remained attentive to signs of discomfort or distress. Participants who

described symptoms suggestive of wound infection or persistent depressive symptoms were supported in seeking appropriate healthcare.

Throughout the study, data were handled confidentially and stored securely in accordance with applicable legislation, including the General Data Protection Regulation. Personally identifiable information was replaced with coded identifiers, and data used for analysis were pseudonymized.

Ethical approvals for the studies included in this thesis were obtained from the Regional Ethical Review Board in Umeå and the Swedish Ethical Review Authority. Data collection in the original GERDA study was approved by the Regional Ethical Review Board in Umeå (Dnrs. 99-326, 05-063 M), and additional approval for studies I and II was granted by the Swedish Ethical Review Authority (Dnr. 2021-00023). The RCTs on which study III was based were approved by the Regional Ethical Review Board in Umeå (Dnrs. 00–137, 08-053 M), and approval for the secondary analyses included in this thesis was subsequently granted by Swedish Ethical Review Authority (Dnrs. 2021–00024, 2021–00681). Study IV and the original HipSTHeR trial were approved by the Swedish Ethical Review Authority (Dnrs. 2021-02283 and 2019-00140, respectively).

Author contributions

Studies I and II: I contributed to the conceptualization and design of the studies, submitted an amendment to the ethical approval, verified hip fractures and dates of death through medical record review, performed the statistical analyses, interpreted the results, and wrote the original draft of the manuscript and revised the manuscript in collaboration with the co-authors.

Study III: I contributed to the conceptualization and design of the study, submitted an amendment to the ethical approval, performed statistical analyses, interpreted the results, and wrote the original draft of the manuscript and revised the manuscript in collaboration with the co-authors.

Study IV: I contributed to the conceptualization and design of the study, submitted the application for ethical approval, recruited and included participants, conducted all interviews, performed the qualitative analysis,

interpreted the findings, and wrote the original draft of the manuscript and revised the manuscript in collaboration with the co-authors.

During the preparation of the included studies and this thesis, artificial intelligence (AI) tools were used for language editing, including grammar correction, synonym identification, and the improvement of English sentence structure, and for the creation of selected illustrations. AI tools were not used for data transcription, data analysis, the interpretation of findings, or the generation of scientific content.

Conclusions

This thesis demonstrates that hip fracture in later life is a complex and life-altering condition that extends beyond an isolated orthopedic injury or an inevitable consequence of aging. The findings show that the hip fracture risk and post-fracture mortality and recovery are associated with a range of functional, clinical, psychological, and social factors.

Among very old adults, greater functional independence was associated with an increased hip fracture risk, suggesting that this risk may reflect not only vulnerability, but also increased exposure to fall-related situations in everyday life. Following hip fracture, mortality was substantial, with nearly half of very old adults dying within 1 year, and depressive disorders emerged as an important factor associated with mortality. Among older adults aged 70 years and older, dementia, both alone and in combination with depressive disorders, was associated with increased mortality up to 3 years after hip fracture. In study IV, recovery was experienced as a dynamic, non-linear process that extended beyond physical healing and involved (changes in) everyday functioning, psychological well-being, social support, and the ability to maintain independence and engage in meaningful activities.

Taken together, the findings highlight the need to move beyond age-based and predominantly physical understandings of hip fracture and toward individualized care that recognizes the different dimensions of exposure, vulnerability, and recovery across the hip fracture trajectory.

Implications for future research

In future research, heterogeneity among older adults with hip fractures beyond chronological age should be examined further. Such work should include the investigation of how very old adults' functional ability and everyday activities interact with the fall and fracture risks, and whether these relationships differ between women and men. The associations among depressive disorders, dementia, and mortality also warrant further investigation, particularly to understand whether potentially modifiable factors related to treatment, rehabilitation, and care processes contribute to differences in outcomes.

Additional longitudinal research is needed to continue the examination of recovery as a dynamic process and to include more diverse groups of older adults with hip fractures. The application of a combined approach including repeated assessments of physical and psychological outcomes and older adults' experiences, as well as family members' and healthcare professionals' perspectives, could provide a more comprehensive understanding of recovery after hip fracture and the factors that influence it over time.

Future research should also move from efforts to identify factors associated with adverse outcomes toward the development and evaluation of approaches that can support recovery across the hip fracture care pathway. Particular attention should be given to the transition from the hospital to primary and municipal care, and to how the continuity and coordination of rehabilitation, psychological support, and functional recovery can be strengthened. Such research could inform interventions that better address the multidimensional and individual needs of older adults following hip fracture.

Implications for nursing and clinical practice

The findings of this thesis highlight the importance of moving beyond age-based assumptions in hip fracture care. Care and rehabilitation should be individualized, with the recognition of what is meaningful to older individuals and how individual needs and priorities may change throughout the recovery period. Assessment and clinical decision making should be undertaken with the consideration of patients' functional ability, cognitive and psychological health, comorbidity, and individual circumstances, rather than chronological age alone.

The findings also suggest that the fracture risk among very old adults cannot be understood solely in terms of frailty or reduced functional ability. Fall prevention measures should be implemented with consideration of individuals' vulnerability and exposure to fall-related situations in everyday life. Differences in risk profiles between women and men further support the application of assessment and prevention strategies based on individual risk factors, rather than assumptions associated with age or sex.

The association of depressive disorders and dementia with increased mortality among older adults with hip fractures emphasizes the importance of recognizing cognitive and psychological health alongside physical and clinical conditions following hip fracture. These conditions should inform the adaptation of care, communication, and rehabilitation to individuals' needs, rather than being viewed as reasons to limit rehabilitation or recovery-oriented care. Such efforts may include the adaptation of communication and rehabilitation strategies according to individuals' cognitive abilities, the provision of additional structure and encouragement, the involvement of family members when appropriate, and the recognition of depressive symptoms that may affect individuals' motivation and participation in recovery.

Recovery after hip fracture extends beyond physical healing and may involve persistent or changing functional, psychological, and social challenges. Although the acute phase of hip fracture care is relatively well defined, recovery continues after hospital discharge, when older adults may experience the fear of falling, reduced confidence, limitations on everyday

activities, and changing support needs. These ongoing factors highlight the importance of follow up that extends beyond attention to physical function and provides opportunities for the identification of functional, psychological, and social needs as they evolve over time. An individualized approach to follow up should also involve the consideration of what recovery means to individuals, including personally meaningful activities, relationships, independence, and goals for everyday life.

The establishment of continuity and coordination among hospital care, primary care, rehabilitation services, and municipal care is thus important to ensure that individuals' changing needs are recognized and addressed throughout recovery. Follow up does not necessarily need to be provided by a member of a single profession or in a single care setting, but responsibility for continued assessment and support should be clear across the care pathway.

Nurses across hospital care, primary care, and municipal healthcare have an important role throughout this process. Their contributions extend beyond assessment and the early identification of changing needs to the support of patients' participation in recovery, the provision of information and encouragement, the involvement and support of family members when appropriate, advocacy for the fulfillment of older persons' needs and goals, and contributions to continuity and coordination across care setting. Through these roles, nurses can support the provision of care and rehabilitation that remain responsive to what matters to individuals throughout the recovery period after hip fracture.

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