Fall-Related Hip Fracture

Predisposing and Precipitating Factors

BREIFFNI LEAVY
Abstract

A physically inactive lifestyle is a predisposing risk factor for fall-related hip fracture. The circumstances, or precipitating factors, surrounding hip fractures are, however, not well understood, a factor of relevance for Swedish adults who have one of the highest hip fracture risks in the world. The aims of this thesis, therefore, were: to explore perceptions of physical activity (PA) among older adults, to describe the circumstances surrounding hip fracture events and the health characteristics of those who experience them.

Four observational studies were conducted involving qualitative, epidemiological and mixed method designs. Participants in study I were recruited from community settings in Stockholm and Dublin (n=30). Studies II-IV (sample sizes, n=484, n=125, n=477) were based on a population-based sample of people admitted to Uppsala University hospital due to hip fracture. Study IV also incorporated the background population of Uppsala county in 2010 (n=117 494).

Analysis of PA perceptions in study I revealed that PA which is functional nature is perceived as most meaningful among certain participants. The uptake of PA in later years was a means of creating a new self-identify and being active in outdoor environments was an important culture-specific motivator to PA among Swedish participants. Analysis of hip fractures patterns in studies II-III showed that: hip fractures among psychotropic drug users were twice as likely to occur during night-time hours compared to those occurring among people not receiving these drugs. Additionally, the fall-related hip fractures of community dwellers with poorest health and function tended to occur indoors during positional changes. In study IV, all categories of disease (according to the International Classification of Diseases, 10th Revision) were seen to be positively associated with hip fracture. Cardiovascular disease and previous injury (including previous fracture) posed the highest relative and absolute fracture risks.

Detailed investigation of hip fracture circumstances reveal patterns in health and functional characteristics, which provide information regarding predisposing and precipitating factors for these events. This knowledge, in combination with findings regarding PA perceptions, can be used when identifying individuals at high risk for hip fracture and when tailoring fracture prevention at an individual level to those at risk.

Keywords: Co-existing disease, Epidemiology, Fall circumstances, Hip fracture, In-depth interviews, Mixed methods, Physical activity perceptions, Psychotropic drugs, Qualitative

Breiffni Leavy, Department of Surgical Sciences, Akademiska sjukhuset, Uppsala University, SE-75185 Uppsala, Sweden.

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We have listened long enough to catastrophic demographic projections of how society will collapse under the expense of providing for all of us old people, it’s like nobody can think in terms of dynamic effects.

Bodil Jönsson, Professor Emerita, Lund University
List of Papers

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

I  Leavy B, Åberg AC. ‘Not ready to throw in the towel’: Perceptions of Physical Activity held by Older Adults in Stockholm and Dublin.

II  Leavy B, Åberg AC, Melhus H, Mallmin H, Michaëlsson K, Byberg L. When and where do hip fractures occur? A population-based study
   Osteoporos Int. 2013 March; 24:2387–2396.

   BMC Geriatrics, Article in Press.

IV  Leavy B, Michaëlsson K, Åberg AC, Melhus H, Byberg L. The Impact of Disease on Hip Fracture Risk.
   Manuscript.

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Abbreviations

ATC       Anatomical Therapeutic Chemical Classification
BMD       Bone mineral density
DXA       Dual-energy X-ray absorptiometry
FRID      Fall-risk-increasing drugs
ICD-10    International Classification of Diseases, 10th Revision
ICF       International Classification of Functioning, Disability and Health
IRR       Incidence rate ratio
MMSE      Mini-mental state examination
OR        Odds ratio
PA        Physical activity
PPAR      Population proportional attributable risk
RR        Risk ratio
RD        Risk difference
RCF       Residential care facility
WHO       World Health Organisation

The definition of concepts used in relation to health in the current thesis, are based on the nomenclature outlined in the International Classification of Functioning Disability and Health (ICF). A depiction of this health model can be seen in figure 1.
Figure 1. Schematic portrayal of the interactional components of the ICF model
### Definition of concepts

<table>
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<th>Term</th>
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<td>Activity</td>
<td>The execution of a task or an action, such as walking.</td>
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<td>Fall</td>
<td>An unexpected event in which the person comes to rest on the ground, floor or a lower level.</td>
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<td>Fall-risk-increasing drugs</td>
<td>A sub-group of drugs strongly associated with increased fall risk which includes drugs acting on the central nervous system (psychotropic drugs) as well as cardiovascular drugs with hypotensive effects.</td>
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<td>Geriatric syndrome</td>
<td>A clinical condition (such as falling) in older people which does not fit into a distinct disease category, and is the result of the accumulated effects of multiple impairments.</td>
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<td>Health</td>
<td>In studies II-IV we use ‘health’ when referring to the levels of co-existing disease and medication use. We use ‘overall health’ when referring to disease, medication status and functional capacity or performance (mobility, personal activities of daily living).</td>
</tr>
<tr>
<td>Older adults</td>
<td>There is no standard definition for older adult, but in westernized countries the most common chronological cut-off point is 65 years. In the current thesis, we refer to ‘older adults’ primarily in relation to participants in study I.</td>
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<td>Physical activity</td>
<td>Any bodily movement produced by the skeletal muscles that require energy expenditure. (Exercise is subset of physical activity involving a planned and structured body movement, performed with an aim of improving or maintaining fitness.)</td>
</tr>
<tr>
<td>Physical inactivity</td>
<td>Can be defined as not meeting any of the following criteria: 30 minutes of moderate intensity aerobic activity, at least 5 days/week or 20 minutes of vigorous activity on at least 3 days of the week.</td>
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Recommended levels of physical activity (for adults ≥ 65 years)

Moderate intensity aerobic activity for 30 minutes, 5 days/week, plus
Moderate intensity muscle strengthening exercise 2–3 days/week, plus
Flexibility exercise for 10 minute bouts 2 days/week.5

Disability
An umbrella term which covers impairments, activity limitations and participation, which reflects the interaction between bodily and societal features.

Participation
Involvement in a life situation.

Polypharmacy
Defined in the current thesis as the use of 5 or more medications from any category.

Psychotropic medications
A group of drugs, such as benzodiazepines, antidepressants, anticonvulsants and narcotics, which by their effects on the central nervous system can impair alertness and neuromuscular function and increase the risk for falls and fractures.6

Predisposing risk factors
Underlying risk factors which make an individual susceptible to disease or health outcomes, such as hip fracture.

Precipitating risk factors
Factors which are responsible for triggering the acute onset of a health outcome, such as a fall, as is the case in this thesis.

Osteoporosis
A systemic skeletal disease in which the density and quality of bone are reduced. Diagnosed in women on the basis of bone mineral density levels which lies 2.5 standard deviations below the mean value for a young white female (BMD T score ≤ 2.5).
Physical activity is an effective way to improve functional capacity in later life, despite the presence of co-existing disease. Conversely, a physically inactive lifestyle, in combination with aging, can lead to muscle weakness and bone loss, commencing a negative health spiral for the older person. One such negative effect of muscle weakness in later life is an increased risk for falls, and physically inactive older people appear especially predisposed to falls and hip fractures. Hip fractures are among the most serious outcomes of falls among older people as they often incur detrimental effects on the functional capacity, independence and mortality of those affected. Previously, hip fracture prevention has focused mainly on the pharmaceutical treatment of bone, primarily using bisphosphonates, and reductions in fracture risk have been demonstrated in women who are younger than 80 years, with diagnosed osteoporosis, or in those with a history of fracture. However, the majority of people with hip fracture do not have bone density levels which fall within the range defined as osteoporosis, and firm evidence is lacking for the efficacy of using bisphosphonates or other bone antiresorptive drugs to prevent fracture in this group. In over 90% of cases however, a hip fracture is preceded by a fall, but details surrounding these falls have scarcely been examined.

Physical activity is the most effective single fall prevention strategy for older adults. It appears that up to one third of all falls in community settings can be prevented by exercise interventions and recent reports indicate that fall prevention can reduce fracture risk at levels comparable to that achievable through pharmaceutical intervention. In consideration of the established benefits of physical activity in later life, the promotion of physical activity among older people should be a public health priority. In order for such promotion to be effective however, an understanding of how older people perceive physical activity is required. This thesis focuses on physical beliefs and fall-related hip fracture occurrence, two domains which strongly influence health and wellbeing in the lives of older people.
Physical activity in later life

That physical activity (PA) benefits health and the management of chronic disease among the general population is widely accepted in the literature. Evidence from observational and intervention studies shows that PA can reduce the risk of: cardiovascular disease, type-2 diabetes, depression and mortality from cancer. The specific physical and psychological benefits of PA among older adults are also well documented. It is also of note that increased exercise uptake after the age of 50 years can lead to lower mortality rates. In consideration of the age-related declines in musculoskeletal strength and postural stability, maintaining an active lifestyle in later life may be especially motivated as evidence suggests that PA can offset these age-related declines in physical capacity. Neither does advanced age contraindicate participation in activities such as strength training, on the contrary, older adults with the lowest strength capacities prior to training have demonstrated the greatest improvements in trial situations. Additionally, weight-bearing exercise appears to have positive, although modest, effects on bone mass in postmenopausal women, making PA a recommended component in the avoidance and management of osteoporosis. These combined effects may therefore explain the reported associations between exercise interventions and reductions in the rate and risk of falls and fractures.

Despite the multitude of established health benefits, levels of PA are decreasing and older people are the least physically active members of society. According to self-report, 60% of Swedish adults, aged 65–84 years meet the PA recommendations of 30 minutes of moderate intensity daily exercise. When more vigorous PA (such as swimming or tennis) is reported however, only 11% of 65–84 year olds are physically active at this level. When PA levels have been objectively assessed, on the other hand, even smaller proportions of older people are reported to meet the recommended PA levels. The most common barriers to PA reported by older people include: health problems, fear of falling, inertia, as well as aspects of the physical environment, such as poor walkability and access to amenities. Culture-specific motivators and barriers to PA have also been highlighted among older populations. A challenge facing PA promotion among older people is that uptake levels of PA programs are low and intervention studies aimed at improving physical function or reducing falls report high drop-out rates among older participants.
Epidemiology of hip fracture

Hip fractures are classified by x-ray confirmation according to anatomical location. Fractures situated proximal to the femoral neck region are referred to as cervical (50 %) and the more distally located fracture types are defined as intertrochanteric (45 %) and sub-trochanteric (5%). Subsequent labelling of hip fractures occurs in reference to the degree of dislocation for cervical fractures, or instability for fractures of the trochanteric region. Hip fracture predominately affects older people, as the majority of fractures occur in people over the age of 70 years. Given the projected growth of the proportion of older people in the population, global hip fracture incidence is projected to rise from a rate of 1.6 million in 2000, to 6 million annually by the year 2050. The risk of incurring a hip fracture differs in relation to geographical location and ethnic identity, with 10-fold variations in hip fracture risk being reported for different countries across the world. Women have a lifetime risk of fracture which is approximately twice that of men and a 50-year-old Swedish woman has a 28 % lifetime risk for hip fracture, placing her amongst those at highest risk in the world. It also appears that falling incidence, bone mineral density and vitamin D levels, can only marginally account for the relatively higher occurrence of hip fracture among the older Swedish population. Additionally, older people living in residential care have up to twice the risk of incurring a hip fracture than elderly people who live in the community. In consideration that hip fracture primarily affects older people, many of whom already suffer from pre-existing health conditions, the impact of hip fracture on morbidity and mortality is often severe.

Mortality rates of up to 33% are reported within the year following hip fracture, with variations dependant on age, gender and health status. Higher excess mortality is reported in men whose rate of death increases by 7-fold in the year following fracture, in comparison to women who have a 4-fold increased excess mortality risk. Among those who survive the consequences of fracture, a substantial proportion of them experience reductions in functional capacity and independence. For instance, for every 100 people who experience a hip fracture, 26 of those who could walk independently before the event, cannot do so a year after the fracture. As a result of these reductions in mobility and functional independence, many older people are unable to return to independent living in the community, which makes hip fracture a frequent reason for admission into residential care facilities. There are also reports that mobility limitation and institutionalisation are more frequently occurring among men who fracture their hip than among women.
The societal burden imposed by hip fracture is higher than all other fractures, as the total cost of caring for one female patient with hip fracture varies between 12,000–18,000 Euro annually, dependant on age at fracture. Estimations of the physical and financial burden imposed by hip fracture however, do not adequately account for the psychological effects incurred by these events. Fear of falling and depression are such two commonly occurring examples, which although not always immediately apparent, are known to influence both functional recovery and quality of life following the fracture.

Risk factors for hip fracture

The risk factors for hip fracture have been studied extensively by prospective cohort studies, but categorization of risk factors is inconsistent in the literature. The most commonly referred to categories are, ‘intrinsic’ (referring to individual risk factors), and ‘extrinsic’ (referring to environmental risk factors). Risk factors for hip fractures can also be thought of as being predisposing—underlying factors which increase susceptibility to fracture (such as age, or physical activity level) or precipitating factors — factors which are responsible for the acute onset of the fall or fracture (such as acute physical symptoms). Regardless of the method of categorization, and owing to the fact that the vast majority of hip fractures occur in combination with a fall, the majority of established risk factors for hip fracture are also proven risk factors for falls. Falls are nevertheless much more frequently occurring than hip fractures in elderly populations as only an approximate 1–2% of all falls are reported to result in fracture of the hip. The interaction of other factors are therefore necessary in explaining why some falls result in fracture whereas others do not. The total number of clinical risk factors, precise fall-mechanisms and bone strength of the person who falls, will also influence whether the fall will result in hip fracture.

Factors related to falling

The British National Institute for Clinical Excellence (NICE) has identified up to 400 potential risk factors for falls among community-dwelling people. The most comprehensive method of classifying fall risk factors is proposed by Lord et al., who divided fall risk factors as follows: Sociodemographic, mobility and balance, sensory and neuromuscular, medical, drug-related and environmental factors. Having a history of falls is one of the strongest predictors of falls and hip fracture among older among community-dwellers. Factors indicative of impaired muscle function, such as impaired mobility, walking aid use and physical disabilities are also proven predictors for falls and subsequent fractures. The presence of diseases
affecting neuromuscular function, such as stroke or Parkinson’s disease are
in turn risk factors for similar reasons. Other shared risk factors for falls and hip fracture among community-dwellers include: increased age, female sex, previous fractures, and balance impairment. There is also evidence for the causal relationship between psychotropic drugs which act on the central nervous system such as benzodiazepines, anti-depressants and anti-convulsants, on falls and subsequent hip fracture. Furthermore, if medications from multiple categories are used, the likelihood of falling increases. The relative effect of fall risk factors may differ in relation to place of residence, and factors which predispose to falls, as well as the impact of these factors, appears to differ between residential care and community settings. In many cases, risk factors can be thought to be inter-related in a fall situation, as is the case for example with psychotropic medications and their effect on postural control. Such medications have been shown to increase the risk for both falls and hip fracture, possibly due to their effects on the older person’s neuromuscular system, which in turn affects gait and postural reactions.

Precise fall mechanisms, such as fall direction and velocity, are also known to influence the impact force transmitted to the greater trochanter and therefore the subsequent fracture risk. A sideways fall with direct hip impact, for example, is a very strong predictor of hip fracture, with risk increases between 6- and 20-fold being reported, dependent on health status. Similarly, whether or not a person manages to break the fall with an outstretched arm will also determine whether the impact energy from the fall can be dispersed.

Factors related to the bone or impact on the bone
Bone mineral density (BMD) is a major determinant of hip fracture as for every standard deviation drop in BMD, there is a continuous (2.6-fold) increase in the risk for hip fracture. The assessment of areal BMD by means of dual-energy X-ray absorptiometry (DXA) is the most widely used clinical measure of hip fracture risk. Hip fractures are, for this reason, often referred to in the literature as osteoporotic or fragility fractures, both terms which imply that an underlying weakened bone structure is influential in fracture causation. This nomenclature is somewhat controversial, as studies have shown that a minority of people with hip fracture have BMD values which can be defined as osteoporotic (BMD T score ≤ 2.5). BMD measurements, at the total hip, are reported to explain 28 % of the risk for hip fracture in women. When the cut-off point is raised in order to include those with less advanced bone density losses, (BMD T score ≤ 1.5) 51% of female hip fracture cases are reportedly explained. However, while those who have a low BMD may have a high risk for hip fracture, those who have
a high BMD do not necessarily have a low risk for hip fracture.\textsuperscript{98} The predictive ability of BMD measures also appears to weaken in line with increasing age,\textsuperscript{99} which is a factor of importance with late-onset fractures such as hip fracture. Another common classification of hip fractures in the literature is that of low-trauma fracture, a term which implies that the causative trauma was a force insufficient to break normal healthy bone, such as the force incurred from a fall from standing height.\textsuperscript{100} Neither can this classification be considered optimal, due to the fact that high trauma hip fractures have also been associated with reduced bone mineral density.\textsuperscript{101} The energy absorption of soft tissues surrounding the hip\textsuperscript{102} or the landing surface\textsuperscript{103, 104} are also factors which can affect the extent of impact to the hip during a sideways fall, which is weakest at this loading point.\textsuperscript{105}

Environmental factors

Environmental factors can contribute to hip fracture by influencing both fall risk, such as in tripping or slipping situations, or by affecting the force of the impact on the bone, which can vary in relation to the landing surface.\textsuperscript{103} The extent to which environmental hazards are reported to explain fall occurrence appears to vary in accordance with study design. Studies exploring older people’s perceptions, on the one hand, commonly describe environmental factors in fall causation,\textsuperscript{106, 107} whereas evidence from cohort studies appears inconsistent with regard to these associations.\textsuperscript{108-111} The transient nature of environmental factors and the mediating effects of functional capacity on exposure to, and the impact of, environmental factors on falls are both possible factors which may explain these disparities.\textsuperscript{108} With the exception of physical function, very little is reported about the presence of other health aspects, such as co-existing disease or medication status, among those who attribute their falls to environmental factors. Additionally, the traditional dichotomous division of fall risk factors as either extrinsic or intrinsic\textsuperscript{112-114} fails to capture the role played by activity-related factors in the run-up to fall events. Evidence is also lacking concerning the extent to which place of residence, which in older ages is often a proxy for general health, or actual weather conditions influence patterns in hip fracture occurrence.
The importance of investigating different perspectives

Fall-related hip fractures have multiple aetiologies and multi-faceted problems call for multiple means of inquiry. The ultimate aim of investigating the circumstances of fall-related hip fracture is to identify patterns which may then be susceptible to change. Similarly, estimating the impact of predisposing factors, such as disease, on hip fracture using epidemiological methods is a way to calculate risk, and in doing so identify individuals who are at high risk. Having identified those who are at-risk for falls or physical inactivity, the next step may often involve encouraging these individuals to change elements of their behavior, by for example becoming more physically active or by using a walking aid. It is however important to remember that the older person in question may not necessarily perceive themselves as being at-risk for negative health outcomes such as falls or fractures.\textsuperscript{115, 116} For these reasons, it is essential to build an understanding of how older people perceive the events which are being promoted or prevented. Findings from qualitative studies investigating physical activity and fall prevention beliefs give rise for concern in these areas.

It has been reported, for example, that many physically inactive older people report ‘lack of interest’ or being ‘too old’ as barriers to exercise.\textsuperscript{117, 118} Additionally, it appears that even older people who have fallen previously tend to underestimate their risk of falling and disregard fall preventive advice as information not personally relevant to them.\textsuperscript{116, 119} Taking account of the preferences of the patient is an inherent element of patient-centered care, and may be especially important in the assessment and rehabilitation of older people who are faced with managing multiple health conditions.\textsuperscript{120} This thesis aims to take these factors into consideration and thereby help to fill gaps in the current literature.
Rationale for the current thesis

In order to tailor exercise interventions which appeal to older people we need to understand the beliefs they hold in relation to physical activity. It is reported that many older people are unaware of the ways in which moderate intensity physical activity can benefit health\textsuperscript{117} or prevent falls.\textsuperscript{119, 121} Over half of those offered to join exercise programs refuse\textsuperscript{115} and it is reportedly the way in which exercise is promoted, which makes older people feel stigmatized and therefore disregard the information.\textsuperscript{122} Although there is extensive evidence for the risks posed by predisposing factors for hip fracture, risk estimates have often been calculated from study populations which have not accounted for the oldest old or the cognitively impaired. Similarly, there is a scarcity of studies which report the relative as well as the absolute risks posed by co-existing disease for hip fracture occurrence. Despite this fact, clinicians are advised to quote the absolute risks when informing patients about treatment options.\textsuperscript{123} To date, hip fracture research has focused on bone-related aspects whereas there is a scarcity of studies which investigate the where, when and how of the fall events which precede hip fractures in over 90 \% of cases. It is therefore feasible to focus hip fracture prevention on the investigation of the circumstances surrounding the fall events which precede hip fracture. It is not known, for example, how factors such as health and residential status effect when hip fracture occurs and it is unclear whether season or actual weather conditions influence hip fracture patterns. Additionally, qualitative studies have highlighted the diversity in causal perceptions amongst older adults who fall and quantitative studies have described predisposing factors for hip fracture, but these factors have rarely been investigated in relation to each other. Placing fall descriptions within the health context of the person who falls may help identify important patterns, which can, in turn, inform preventive efforts.
The overall aims of this thesis were:
To explore the physical activity perceptions of older adults, to describe the characteristics of people with hip fracture as well as the situational circumstances of fall-related hip fracture events.

The specific aims of Studies I–IV were:

I. To explore and describe the physical activity perceptions held by older urban adults in Sweden and Ireland.

II. To investigate whether the timing of hip fracture occurrence varied in relation to the subject’s health, residential status, or fall location and to examine the effect of season and weather on hip fracture incidence.

III. To investigate the circumstances surrounding fall-related hip fracture and to describe fall circumstances in relation to participants’ health and functional characteristics.

IV. To report the relative and absolute risks posed by a comprehensive range of disease categories for the occurrence of hip fracture, using a population-based cohort design.
Methods

This work has an exploratory approach which incorporates research into two domains affecting the health and well-being of elderly people, namely hip fracture occurrence and physical activity beliefs. The aims of the thesis varied in nature from describing subjective experiences to calculating risks estimates which are applicable at a population level. In consideration that different aspects of reality lend themselves to different methods of inquiry, the adoption of different paradigmatic traditions, or ‘viewing positions’ were required. A paradigm or methodology is the ‘basic set of beliefs, brought to the study by the researcher which influence the techniques used to answer the specific research questions. Whereas methodologies have been defined as ‘thinking tools’, methods on the other hand have been described as ‘doing tools’ are not uniformly linked to paradigms. The various investigations incorporated in this thesis are underpinned by naturalistic, postpositivistic and pragmatic methodologies which in turn utilize qualitative, epidemiological, and mixed-method research designs. The chosen research methods of each design then translate each approach into practice.

Naturalism using interview technique

Study I was carried out in a naturalistic tradition as questions regarding people’s beliefs in relation to physical activity lend themselves to qualitative approaches. Qualitative inquiry is concerned with exploring the experiences and social contexts of participants. The ontological belief of such an approach is that multiple realities exist, and these realities are constructed through lived experiences. Face to face interviews were used as the method to access perceptions of PA in Study I and descriptions of fall circumstances in study III. In the naturalistic tradition, knowledge obtained through interviews is considered contextual and open to multiple interpretations. Resultantly, researcher objectivity is considered neither necessary nor advisable, as subjective experiences of the researcher are considered part of the process of interpretation. The analysis of interviews in studies I and III focused on the development of categories, derived inductively from the data. The choice of the qualitative method of analysis gives rise to findings which can vary on a continuum in relation to the degree of transformation of the
data. This may range from descriptive results at lower levels of abstraction to those which progress to more interpretative or explanatory domains.\textsuperscript{132}

**Postpositivism and epidemiology**

Studies II and IV had quantitative approaches which are rooted in postpositivistic traditions. Postpositivistic inquiry has a deterministic philosophy where causes or exposures determine the effects or outcomes and these relationships can be deductively ascertained by objective neutral processes.\textsuperscript{131} In order to answer the specific research questions in these studies, epidemiological methods were employed, which are concerned with measuring the occurrence of disease in relation to the population at risk. The axiological beliefs in this tradition are that bias, whether random or systematic in nature, is an error and attempts should therefore be made to control for these errors.\textsuperscript{133} The use of epidemiological methods and statistics in studies II and IV had the view of adopting an estimation approach, which involves reporting the magnitude and precision of an estimate, by means of the point estimate and confidence intervals respectively.\textsuperscript{133} This approach differs from that adopted when hypothesis testing is in focus.

**Mixed methods**

Study III was a mixed methods study, the guiding interpretative framework of which is pragmatism. The assumptions of pragmatism are that data collection and analysis is determined by nature of the study aims.\textsuperscript{134} Pragmatists believe that a richer analysis of the phenomenon can be achieved by tapping the relative strengths of positivistic and naturalistic methods.\textsuperscript{135} The integration of methodologies is therefore allowed, and pragmatism adheres, in general, to the belief that ‘a false dichotomy exists’\textsuperscript{136} between qualitative and quantitative data. The rationale for this approach in study III was that of complementarity, whereby participant descriptions of the fall which preceded hip fracture could provide insight into one aspect of fall circumstances and quantitative health data could elaborate and enhance these descriptions.\textsuperscript{134}
Theoretical perspectives

Investigation of multifactorial phenomena may be aided by the use of theories and schematic models which portray how multilevel factors interact to result in health outcomes among older people. Such models are based on the assumption that patterns of health and well-being are affected by a dynamic interplay between biological, behavioral and environmental factors. The use of more comprehensive conceptual models in relation to health outcomes also serves to highlight multiple points of possible intervention. The below described theories and associated models provided a theoretical basis from which hip fracture occurrence and PA perceptions were viewed throughout this work.

International Classification of Function, Disability and Health

The dynamic interaction of different domains on health is reflected in the World Health Organizations’ model: International Classification of Function, Disability and Health (ICF). The ICF is a framework for describing health and disability and commonly used in rehabilitative medicine. In the current work, the ICF was used as a general conceptual model concerning the areas PA perceptions and fall-related hip fracture. The ideology of the ICF model (Figure 1) is that biological, individual and social perspectives interact to result in health outcomes. A person’s activities and participation in everyday life can therefore be viewed from such biological, psychosocial and social perspectives.

The fall risk triangle

The fall risk triangle is an example of a health model which was designed specifically in relation to falls and can be used in the investigation of fall risk or planning of fall prevention at individual or group level (Figure 2). This schematic depiction of the interplay between multiple factors outlines three factor groups of pertinence in falls investigation; individual capacity, environmental and activity-related factors. In the current thesis, the model was used as a thought structure in the design of the interview protocol and questionnaire relating to fall events. Terminology in the fall risk triangle is in line with language used in the ICF framework whereby: ‘Capacity’ incorporates aspects of physical, cognitive, medical status such as for example, balance, muscle strength or co-existing disease; ‘Activity’ incorporates the activity at the time of the fall and the way in which it was performed, and ‘Environment’ relates to physical and psychological aspects, such as flooring, lighting or stress.
Ethical considerations

All participants in study I gave their informed consent to participate in the study. Ethical permission was not necessary according to the current legislation at that time. Ethical approval was sought and approved by the Regional Ethical Review board in Uppsala for studies II-IV.

Qualitative interviews are by nature intrusive as they seek to access personal experiences and, in the case of hip fracture events, have the potential to evoke traumatic memories. A range of precautions were therefore undertaken to ensure the ease of all interviewe d participants. Potential participants with hip fracture were firstly identified by a review of hospital records. The responsible nursing staff member for each patient was then consulted regarding the medical status of the individual in relation to the study inclusion criteria. When appropriate, patients were approached by the author, who explained the nature of the study and clarified her role as researcher and therefore not a member of the hospital staff responsible for the persons’ health care. People then received written information of the study and were given a day or two to review before being re-approached for confirmation of whether they wished to participate. Participants in study I chose a time and place for the interviews, and in study II and III, chose a suitable time and location within the hospital setting. All participants were reminded that interviews were voluntary and that withdrawal from the study would not be questioned.
Participants

Participants included in this thesis came from two separate study populations, a population of healthy community-dwelling older adults in Dublin and Stockholm (Study I), and a population-based cohort of people admitted to Uppsala University hospital with hip fracture (Study II-IV). An additional study population was used in study IV and incorporated the source population of all people over the age of 50 years (born in 1960 or before), who were registered as residing in Uppsala County during the study period. An overview of study participants, design and methods is displayed in table 1.

Study I

Purposive sampling\(^{141}\) was the method used to ensure a diversity among 15 Swedish and 15 Irish participants with regard to physical activity level, age, gender and geographic location within the respective cities. Voluntary organizations such as active retirement groups and day centers for the elderly were used as a source for recruiting participants to the study. Active participants were recruited most often through active retirement groups, whereas contact with the lesser active participants tended to be made at day centers which served more as a social meeting point, and did not have physical activity on their agenda. The author, with the help of contact people from these organizations then selected potential participants according to the specific sampling criteria. To be eligible for participation in the study participants were required to be: 65 years and older, living in their own homes and functionally independent regarding activities of daily living. Cognitively impaired people were not eligible for inclusion, a factor which was judged by the contact person to whom participants were familiar.

Study II and IV

The study population in studies II and IV consisted of people aged 50 years and older, who were consecutively recruited on the basis of admission to Uppsala University Hospital with radiographically confirmed hip fracture, during the 12-month period 8\(^{\text{th}}\) June 2009–8\(^{\text{th}}\) June 2010. Those with pathological fractures (n=5), periprosthetic fractures (n=12) and cases where surgical treatment did not occur at Uppsala University Hospital (n=15) were excluded, and four people died post-surgery, leaving 484 people with hip fracture in the study population. (This number then sank to 477 in study IV as a result of further cross-checking of hip fracture cases). As previously mentioned, the source population of all people who were residing in Uppsala county (n=117 494) in 2010, constituted an additional population in study IV.
Study III
This study population consisted of 125 individuals who were consecutively included from people, aged 50 years and older, admitted to Uppsala University Hospital with radiographically confirmed hip fracture, during 10-months (September–June) of the above described 12-month period (Study II and IV). In addition, participants were required to fit the following criteria: at least partial memory of the fall, verbal ability to recount fall details and a Mini-mental state examination (MMSE) score ≥24 points. In consideration of the study aims, those with reduced consciousness, post-operative confusion or medical instability were not considered for participation.

Figure 3. Flow chart over inclusion of participants in studies II–IV. Colour scheme: Study II (light/dark grey), Study III (yellow), Study IV (orange). ¹Further case identification lead to the removal of 7 cases between study II and IV.
Table 1. Overview of design and methods for study I – IV

<table>
<thead>
<tr>
<th></th>
<th>Study I</th>
<th>Study II</th>
<th>Study III</th>
<th>Study IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Design</strong></td>
<td>Qualitative</td>
<td>Population-based cohort study</td>
<td>Concurrent triangulation mixed methods</td>
<td>Population-based cohort study</td>
</tr>
<tr>
<td><strong>Sampling strategy</strong></td>
<td>Purposive</td>
<td>Population-based cohort</td>
<td>Purposive</td>
<td>Population-based cohort and the underlying population in the region.</td>
</tr>
<tr>
<td><strong>Study population</strong></td>
<td>30 community-dwelling adults aged ≥ 65 years, 15 living in Dublin, 15 living in Stockholm.</td>
<td>484 people with hip fracture, aged ≥ 50 years, admitted to an acute hospital setting, consecutively included during a one-year period.</td>
<td>125 people with hip fracture, aged ≥ 50 years, MMSE score ≥ 24, who had memory and ability to verbally recount fall details.</td>
<td>i) 477 people with hip fracture, aged ≥ 50 years, admitted to an acute hospital setting, consecutively included during a one-year period. ii) Source population of Uppsala County, aged ≥ 50 years during the study period.</td>
</tr>
<tr>
<td><strong>Data collection</strong></td>
<td>In-depth interviews</td>
<td>Medical journal access</td>
<td>Individual interviews</td>
<td>Data for disease diagnosis registered in the Swedish National Patient Register during the observation period 1964-2010 for study populations.</td>
</tr>
<tr>
<td></td>
<td>Thematic text analysis</td>
<td>Interview administered questionnaires</td>
<td>Interview-administered questionnaire.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Face to face and telephone interviews</td>
<td>Hand dynamometer.</td>
<td></td>
</tr>
<tr>
<td><strong>Data analysis</strong></td>
<td>Logistic regression</td>
<td>Qualitative content analysis</td>
<td>Qualitative content analysis</td>
<td>Calculation of age and sex-stratified incidence proportions of hip fracture among exposed and unexposed to each disease category.</td>
</tr>
<tr>
<td></td>
<td>Poisson regression</td>
<td>Descriptive statistics</td>
<td>Analysis of variance for age</td>
<td>Calculation of age- and sex-standardized risk ratios (RR’s) and risk differences (RD’s) by sex and 5-year age category.</td>
</tr>
<tr>
<td></td>
<td>Population proportional attributable risk (PPAR)</td>
<td>Analysis of variance for age</td>
<td>Fisher’s exact test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generalized linear models</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Data collection and analysis

Study I – A qualitative study

Interviews were conducted mostly in participant homes or in the meeting place of their groups, in accordance with their individual wishes. The 15 interviews in Dublin were conducted in English and the 15 interviews in Stockholm were conducted in Swedish and lasted between 30 to 75 minutes. All interviews commenced with the same opening question – ‘What are your thoughts on physical activity?’ The participants were then encouraged to speak freely around specific themes relating to physical activity such as motivators and barriers, available information and if and how they believed physical activity to affect health. Transcribed interview material in this study was content-analyzed in accordance with the ‘thematic framework’ approach. Each transcript was firstly individually reviewed to identify the relevant topics that related to participants’ perceptions of physical activity, these were termed initial codes. These initial codes were then applied to all transcripts one at a time by a process of labeling. This analysis yielded preliminary interpretations of each participant’s perceptions, which were reanalyzed and checked against the transcribed material. Sub-themes and main themes were discussed and chosen by the authors so as to most accurately encompass and reflect participants’ perceptions during earlier stages of the analysis.

Study II – A population-based cohort study

Data collection occurred during hospital stay. Sociodemographic details and data concerning the fracture type, month of fracture, surgical reparation, comorbidity and medication were gathered from subjects’ medical records. Place of residence prior to the hip fracture was defined as either community-dwelling or residential care facility (RCF), whereby RCF was a collective term for serviced apartments and nursing homes for elderly people in greater need of medical care. Based on place of residence and fall location data, subjects were divided into three groups; community-dwellers who fractured outdoors, community-dwellers who fractured indoors, and those who lived in a RCF at the time of fracture. Diseases were defined according to International Classification of Diseases (ICD-10) categories as follows: Cerebrovascular diseases (I6), Ischaemic heart disease (I20-I25), Hypertension (I12 I15 I10.9 I11.9), Dementia (F00-F03, F05.1) and Depression (F32-F33, F20.4 F25.1 F31.3-F31.5 F41.2 F92.0). We further calculated the number of comorbidities using Charlson’s Comorbidity Index as a measure of overall comorbidity for each subject. Drugs were defined according to the Anatomical Therapeutic Chemical (ATC) classification system as: Benzodiazepines
(N05BA), Sedatives (N02A, N05B-C), Antidepressants (N06A, N06CA-B) and Diuretics (C03C). We defined Polypharmacy as the use of five or more medications and psychotropic drugs as the use of at least one drug from the categories N05A-C or N06A-C.

The time of day at which the fracture occurred, estimated to the closest hour, was reported by 334 hip fracture cases (78 % of eligible cases) included in an interview sub-study. Verbal and written informed consent was obtained from these subjects or from their family members or care providers, in the case of cognitive impairment (MMSE score ≤ 24 points). All interviews were carried out within one week of the fracture event. When subjects could not personally relate the time of the fall event which lead to hip fracture, due to; reduced consciousness, language difficulties, delirium or cognitive impairment, this information was collected by telephone interview with a family member when the subject lived in the community (n= 75), or from a care nurse from the subject’s RCF (n=90).

Weather data concerning daily snow depth (cm) for Uppsala County for the study period was obtained on request from the Swedish Meteorological and Hydrological Institute.

Statistical analysis
Logistic regression analysis was used to determine the age-adjusted odds ratios (OR) as a measure for the prevalence of comorbidities and medication usage between the three above-described subject groups. Logistic regression was also used to estimate the effect of psychotropic drugs or dementia (or both) on nighttime fractures and ORs were adjusted for the effects of age and Charlson comorbidity index. Poisson regressions were used to compare the fracture incidence rate between days where the ground was snow-covered and days of no snow cover and presented as incidence rate ratios (IRR). The population proportional attributable risk (PPAR) of hip fracture due to snow coverage for the entire sample/community-dwelling subjects was estimated using the formula: PPAR = \frac{Prevalence_{\text{exposure}} \cdot (RR-1)}{1 + Prevalence_{\text{exposure}} \cdot (RR-1)}\), where Prevalence_{\text{exposure}} is prevalence of the exposure (days with snow cover) and RR the risk ratio obtained through Poisson regression. Variation in time of fracture was modeled using generalized linear models with a Poisson distribution, by applying combinations of sine and cosine terms with varying wavelength up to the sixth harmonic or combinations of linear, quadratic and cube functions both for the 24-hour period and for the months of the year. The Bayesian Information Criteria (BIC) statistic was used as a criterion for model selection as it resolves the problem of overfitting, by introducing a penalty term for the number of parameters in the model. In situations where only one peak was observed in the model, we used a
directional statistical method to evaluate seasonal variation in fracture occurrence. These analyses were performed separately for the three groups based on living status and fall location, as well as for those with and without dementia/psychotropic drugs. Stata version 11.0 (Stata Corp., College Stn, TX, USA) was used for the statistical analyses.

Study III – A concurrent triangulation mixed method study

Collection of the qualitative and quantitative data

With this design, qualitative and quantitative data were collected concurrently, analysed separately and then merged. Data concerning fall circumstances were collected during semi-structured interviews, performed by the same investigator, where participants were encouraged to speak freely while describing fall events. An interview guide was used and commenced with the open question: ‘Can you describe for me what happened when you fell and broke your hip?’ These open-ended questions were then followed by probing questions which aimed to investigate the eventual influence of other specific environmental, individual or situational factors which may have played a role in the fall occurrence. Interviews varied in length from 8 to 25 minutes and were recorded and transcribed verbatim. Each interview was then followed by an interview-administered questionnaire which contained closed-answer questions concerning more specific details of the fall. This section of the questionnaire regarding fall details was developed with reference to previous hip fracture studies on fall mechanisms.

Health data questions were incorporated into the interview-administered questionnaire and were developed with reference to previously existing health-related questionnaires tested in earlier epidemiological studies of fractures. Questions related to prior performance of personal activities of daily living, mobility, balance, previous falls and PA participation were categorized as described in the section ‘Analysis of the health data’. Hand grip strength was tested, by the same investigator, using the ‘Baseline’ hydraulic hand dynamometer (Fabrication Enterprises Inc.) with the elbow flexed at 90 degrees and the participant sitting in a high-lying position. Three maximal grip contractions of the dominant hand were performed, the mean value of which was then calculated. Data concerning pre-fracture comorbidity and medication were retrieved from medical records. Comorbidity was categorized as 0, 1 and ≥ 2 chronic diseases, based on Charlson’s unweighted comorbidity score, calculated from ICD-10 diagnoses. Fall-risk-increasing drugs (FRIDs) were categorized as: no FRIDs, psychotropic FRIDs (PsyFRID; ATC codes N02A, N03A, N04A-B, N05A-C, N06A), cardiovascular FRIDs (CvdFRID; ATC codes C01A, C01BA, C01D, C02, C03, C07-C09, G04CA) and concomitant use of PsyFRID and CvdFRID.
Analysis of the interviews

Qualitative content analysis was the method used due to analyse the interview data where a step-by-step analysis is used to highlight patterns in the data according to phenomenon being studied.\textsuperscript{150, 151} Content analysis has been described by Krippendorff as “the use of replicable and valid method for making specific inferences from text,”\textsuperscript{152} with the overall aim of making a condensed and broad description of a particular phenomenon. Our interview data also consisted of relatively short interviews which further motivated the choice of a method which allows data to be interpreted at various levels of abstraction. Based upon the study aims as well as the nature of the interview material, we chose to perform a manifest analysis, which aims to analyse content close to the text.\textsuperscript{153} We also chose to approach the text inductively without preconceived categories.\textsuperscript{154} The analysis was performed as described by Graneheim and Lundman\textsuperscript{153} in the following stages: i) The interviews were read through several times to get a sense of the whole ii) Domains relating to areas of the text relating to causal factors for the falls were heighted iii) The meaning units of analysis were selected in direct relation to the study aims and involved sections of the text referring to perceived cause of the fall iv) Meaning units were then condensed and part of the texts were labeled to derive codes v) Codes of similar nature were then grouped to form sub-categories and then four main categories which can be identified as a thread throughout the codes.\textsuperscript{153} The analysis process involved a back and forth movement between the selected codes and the interviews as a whole. The first author was responsible for the primary coding of all interviews and the last author acted as a peer to the first author through a process of review and discussion of the credibility of categories in the data.

Analysis of the health data

Pre-fracture mobility was divided into the categories ‘Low’, ‘Moderate’ or ‘High’ which were defined as follows: Low (required a walking aid indoors); Moderate (required a walking aid outdoors only), High (no walking aid required). Participation in personal activities of daily living was categorized as independent /dependent in \( \geq 1 \) activity of personal care, whereby for example participants who required assistance or supervision during bathing were considered dependent in one activity. With regards to PA participation, participants answering ‘hardly any exercise’ to the question ‘How much exercise did you engage in prior to the fracture?’ were classified as ‘Sedentary’, with other divisions including ‘Light exercise’ (Lighter exercise such as regular walks or gardening) or ‘Hard physical exercise’ (Do you engage in hard physical training or sport?). This question was based on a questionnaire, created in collaboration with the Swedish national institute of health which measures lifetime physical activity,\textsuperscript{155} which has been used in previous cohort studies of older Swedish populations.\textsuperscript{9, 52} Absolute grip strength values
were compared with published normative grip strength data, and stratified according to age, gender and height. ‘Low’ grip strength incorporated values between the 10th and the 5th percentile of normative data and ‘Abnormally low’ grip strength as those under the 5th percentile of normative data. In this calculation, 7 individuals (1 man and 6 women) lacked height data so for these we used the median height in the sex-specific age group in our sample (women ≥ 65 years: 164 cm; men ≥ 65 years: 175 cm). This imputation was only used for the definition of low grip strength.

The two forms of data were then merged in the results section using a joint display of the data and then interpreted in the discussion section. To facilitate the integration of the data sets, qualitative fall circumstance categories were treated as categorical variables. We organized the data in relation to the fall circumstance categories, which were viewed in relation to variables of health and function using cross tabulation and descriptive statistics. This triangulation of data occurred during both the analysis and interpretation phases with the purpose of interrelating and identifying patterns in the data.

**Study IV – A population-based cohort study**

**Outcome and exposures**

The outcome under investigation was admission for radiographically confirmed hip fracture (S72.0–S72.2 according to ICD-10) to Uppsala University Hospital, during the 12-month period, 8th June 2009–8th June 2010. Each hip fracture case was individually validated by crosschecking medical records which ruled out misclassification of events. Pathological (n=5), periprosthetic (n=12), and those fractures where surgical treatment did not occur at Uppsala University Hospital (n=15) were excluded.

Exposures in the current study included all diseases registered under the primary and secondary diagnoses in the Swedish National Patient Register (NPR). The NPR contains data concerning disease diagnosis registered during hospital admissions from 1964 and onwards. Diagnoses in broad categories according to the ICD-10 were as follows; infectious and parasitic diseases (A00-B99); malignant tumors (C00-C97); non-malignant tumors (D00-D48); diseases of blood/blood forming organs (D50-D89); endocrine, nutritional and metabolic disorders (E00-E90); mental and behavioural disorders (F00-F99); diseases of the; nervous system (G00-G99); eye (H00-H59); ear (H60-H95); circulatory system (I00-I99); respiratory system (J00-J99); digestive system (K00-K93); skin and subcutaneous tissue (L00-L99); musculoskeletal system (M00-M99); genitourinary system (N00-N99); previous injury (S00-T98) and fracture injury (S 12/22/32/42/52/62/72/82), which was
a subcategory of injury. Data were extracted such that each diagnosis could be counted once per individual during the observation period 1964-2010. For subjects with two hip fractures during the observation period (n= 7), the date of the second fracture was used as the index date, to prevent diseases being diagnosed more than once for the same individual. Data extraction was performed in a similar way for both the hip fracture cohort and for the source population.

**Statistical analysis**

Using the 477 subjects with hip fracture during a one-year period as outcome, the underlying population was included as a reference population in a cohort analysis. Age was divided into 5-year strata and subjects aged 85 years and above were included in an additional category. The prevalence of each disease category was calculated for both the hip fracture cohort and source population. Age and sex-stratified incidence proportions of hip fracture were calculated among those exposed and unexposed to each disease category. These calculations were then used to estimate the age- and sex-standardized risk ratios (RR’s) and risk differences (RD’s) of hip fracture in the total population, and separately by sex, and age category (50-69; 70-79; 80+) using total number of exposed as internal weights. Statistical analyses were performed using Stata 11.0 (Stata Corp., College Station, TX, USA).
Findings

Perceptions of physical activity (Study I)

Participants were divided into three groups in relation to how physically active they described themselves as being: Active (involved in planned PA of non-functional nature, at least three times a week), moderately active (engaged in some weekly PA which was often unscheduled and functional in nature) and inactive (not engaged in PA of any kind outside of the home). Three central themes were identified in relation to participants’ perceptions of PA. These were: PA as self-perception, PA as interaction and PA as health promotion.

Active participants often claimed not to need external motivators to be physically active as, for them, PA was a lifestyle and an inherent part of self-identity. The uptake of PA in retirement years was also discussed by others as a means of establishing a new self-identity. For these ‘late starters’, becoming physically active was perceived as a means by which they could invest in themselves, as well as a way to adapt to major lifestyle changes which occurred in connection with retirement or children leaving the home. However, not all participants adapted to retirement in the same way, as inactive men from both cultures appeared to identify strongly with former occupations and spoke of how the consequences of their previous working life had negatively affected their health and thus explained their current levels of inactivity.

All participants acknowledged the physical or mental health benefits associated with PA, but variations existed in the extent to which people believed that PA could affect their personal health. More active participants had in general, strong beliefs about the physical and psychological health benefits of PA. They viewed symptoms from chronic conditions as a motivating factor to remain physically active and had altered the nature of their PA to adapt to declines in capacity in the attempt to remain active. Lesser active people, on the other hand, spoke of how symptoms such as joint pain or breathlessness reduced or prevented them from being physically active. Some of these lesser active participants expressed feeling unsure and uninformed regarding whether physical exertion was advised or not in the presence of symptoms of chronic disease. Some moderately active participants expressed skepticism
towards the targeting of certain forms of exercise towards older people. They believed gym-based exercise to be nonsensical and placed a higher value on exercise that was of functional nature.

Cultural differences were most evident in terms of the interactive role played by PA. Social interaction with peers was stressed to a greater extent among Irish participants whereas outdoor pursuits in natural environments featured more strongly as a recurrent motivator to PA among Swedish participants, of all PA levels. Physically inactive participants (from both cultures) often expressed a desire for greater social contact, but felt confined to their home environment by physical ailments.

When and where hip fractures occur (Study II)

A total of 484 hip fracture cases were included in this study. Of the total cases, 338 (69.8 %) were female. The mean age at fracture was 82.7 years in women (range, 51–104) and 79.5 years in men (range, 52–98). In total, 375 (80.3 %) fractures occurred indoors and of those which occurred in residential care, all except for six cases, occurred indoors. Gender was not seen to be associated with either type of hip fracture or fall location. We divided subjects into three groups, based on place of residence and fall location at the time of fracture; community-dwellers who fractured outdoors (n=62, 18 %), community-dwellers who fractured indoors (n= 234, 50 %), and subjects who fractured in a residential care facility (n= 151, 32 %).

In relation to health status, residential care dwellers had a higher prevalence of disease and medication use than those living in community settings. When controlled for the effects of higher age, subjects living in RCFs were more likely to suffer from dementia (OR: 11.34; 95% CI: 6.26–20.57) and to be receiving a greater number of fall-risk-increasing medications (OR: 3.35; 95% CI: 2.07–5.45), than community-dwellers who fractured indoors.

In relation to the time at which fracture occurred, community-dwelling subjects showed a peak in fracture occurrence between 12 and 2 o’clock in the afternoon, regardless of whether the fall occurred indoors or outdoors. Those living in RCFs, on the other hand, showed no daytime peak in the fitted frequency model and demonstrated a greater tendency to fracture during evening and night-time hours (Figure 4) than community-dwellers who fractured indoors (OR: 1.37, 95% CI: .86–2.10).
In consideration of the high prevalence of dementia and use of psychotropic drugs among RCF dwellers, we examined the association between nighttime fractures and psychotropic drugs. Subjects using psychotropic drugs, were also twice as likely to fracture during nighttime hours (Adj. OR: 2.20, 95% CI; 1.12–4.30) compared to those not receiving these medications (Figure 5). Even when subjects with a dementia diagnosis were excluded from the analysis (n= 75), the associations between psychotropic drugs and nighttime fracture remained (OR: 2.91, 95% CI; 1.40–6.0). This trend was also observed, albeit with a weaker association among community-dwellings subjects (Adj. OR: 2.31, 95% CI; .98–5.42).

**Figure 4.** Time of fracture according to residence and fall location. The fitted functions were: Panel a (Community-dwellers who fractured indoors, n=166); Panel b (Community-dwellers who fractured outdoors, n=62) and panel c (Residential care facility dwellers, n=104).

**Figure 5.** Time of fracture according to psychotropic drug use. The fitted functions were: Panel a (subjects without dementia not using psychotropic drugs, n=136); Panel b (Subjects using psychotropic drugs, n=181) and Panel c (Subjects using psychotropic drugs without a dementia diagnosis, n=123).
Although we did not observe a seasonal pattern in hip fracture variation, based on month, we reported that on days of snow cover, community-dwellers, as a whole, had a heightened hip fracture incidence rate (IRR: 1.32, 95% CI: 1.05–65). This increased risk was seen both indoors and outdoors. The population proportional attributable risk of hip fractures that occurred due to snow was calculated as 5.5% for the entire subject group and 9% for community-dwelling subjects.

Circumstances surrounding fall-related hip fractures (Study III)

Fall circumstances

Participant descriptions of fall circumstances are presented in relation to two main domains, Activity at the time of the fall (Table 2 and 3) and Nature of the fall (Table 4 and Figure 6).

Table 2. Activity at the time of the fall of the 125 interviewed participants

<table>
<thead>
<tr>
<th>Activity, n (%)</th>
<th>Indoor</th>
<th>Outdoor</th>
<th>Total n=125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positional change</td>
<td>23 (27.7)</td>
<td>1 (2.3)</td>
<td>24 (19.2)</td>
</tr>
<tr>
<td>Sit-to-walk&lt;sup&gt;1&lt;/sup&gt;</td>
<td>20 (24.1)</td>
<td>1 (2.3)</td>
<td>21 (16.8)</td>
</tr>
<tr>
<td>Stand-to-sit&lt;sup&gt;2&lt;/sup&gt;</td>
<td>3 (3.6)</td>
<td>0</td>
<td>3 (2.4)</td>
</tr>
<tr>
<td>Standing</td>
<td>13 (15.6)</td>
<td>3 (7.1)</td>
<td>16 (12.8)</td>
</tr>
<tr>
<td>Standing still</td>
<td>6 (7.2)</td>
<td>0</td>
<td>6 (4.8)</td>
</tr>
<tr>
<td>Standing &amp; bending/reaching</td>
<td>7 (8.4)</td>
<td>3 (7.1)</td>
<td>10 (8.0)</td>
</tr>
<tr>
<td>Walking</td>
<td>41 (49.4)</td>
<td>31 (73.8)</td>
<td>71 (56.8)</td>
</tr>
<tr>
<td>Forward walking</td>
<td>29 (34.9)</td>
<td>29 (69.1)</td>
<td>57 (45.6)</td>
</tr>
<tr>
<td>Turning while walking</td>
<td>12 (14.5)</td>
<td>2 (4.8)</td>
<td>14 (11.2)</td>
</tr>
<tr>
<td>Balance challenging</td>
<td>7 (8.4)</td>
<td>7 (16.6)</td>
<td>14(11.2)</td>
</tr>
<tr>
<td>Walking on stairs</td>
<td>3 (3.6)</td>
<td>1 (2.3)</td>
<td>4 (3.2)</td>
</tr>
<tr>
<td>‘Hazardous’&lt;sup&gt;3&lt;/sup&gt;</td>
<td>4 (4.8)</td>
<td>6 (14.3)</td>
<td>10 (8.0)</td>
</tr>
</tbody>
</table>

<sup>1</sup>Falls during the initial 3 meters of walking having risen from a sitting/lying position,  <sup>2</sup>Falls while transferring from a standing to a sitting/lying position,  <sup>3</sup>Falls during complex activities, such as from: bikes, stools, ladders or while running or sledging.
Nature of the fall

Indoor falls (n=83, 66%):  
*Environmental* (n= 32, 26%); falls described as primarily precipitated by environmental conditions or objects, which included the subcategories: trips over; mats (n=5), thresholds (n= 3), and; household objects (n=10), slips on wet surfaces (n=8) and inadequate footwear, (n=7).  
*Physiological* (n=35, 28%); falls described as precipitated by physiological factors, with no environmental component and included the subcategories: self-induced disequilibrium – a symptomless loss of balance during normal body movements (n=14); falls proceeded by physical symptoms such as dizziness or faintness (n=13) and reduced function or pain of the lower limb (n=6).  
*Activity-related indoor* (n=8, 6%); falls precipitated by the complex nature of the activities engaged in, such as standing on one leg or on kitchen stools.

Outdoor falls (n=42, 34%):  
*Trips & slips, snow* (n=20, 16%); slipping and tripping on snowy or icy surfaces.  
*Trips & slips, no snow* (n=12, 10%); slipping and tripping on snow and ice-free surfaces; *Activity-related outdoor* (n=8, 6%); falls during high speeds (n=2) or from ladders (n=3) or bikes (n=3). The category *Unknown* (n=10, 8%) incorporated falls of unexplained nature occurring both indoors (8/10) and outdoors (2/10).

Patterns between fall circumstances and health characteristics

Those who fell during positional change had the poorest functional status

Participants whose fall-related fracture occurred during *positional change* appeared to be those with greatest functional limitations. Support for this pattern in the quantitative data was primarily seen in relation to mobility and limitations in personal activities of daily living (Table 3). Additionally, this group more frequently rated themselves as being sedentary, having ‘bad’ balance and having fallen previously. In terms disease prevalence and medication use, patterns were somewhat divergent as differences were not significant from other groups. Nevertheless, support for this pattern was present in the interview data as the majority of those who fell during *positional change* frequently described physiological symptoms of chronic conditions or poor health as precipitants for their falls.
<table>
<thead>
<tr>
<th>Health characteristic</th>
<th>Positional change&lt;br&gt; n=24</th>
<th>Standing&lt;br&gt;n=16</th>
<th>Walking&lt;br&gt;n=71</th>
<th>Balance-challenging&lt;br&gt;n=14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years (mean (SD))</td>
<td>81.4 (10.3)</td>
<td>78.7 (9.3)</td>
<td>79.4 (8.7)</td>
<td>76.7 (9.1)</td>
</tr>
<tr>
<td>Gender (female)</td>
<td>16 (66.7)</td>
<td>11 (68.7)</td>
<td>52 (73.3)</td>
<td>10 (71.4)</td>
</tr>
<tr>
<td>Mobility&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low&lt;sup&gt;2&lt;/sup&gt;</td>
<td>15 (62.5)</td>
<td>3 (18.8)</td>
<td>17 (23.9)</td>
<td>1 (7.4)</td>
</tr>
<tr>
<td>Moderate&lt;sup&gt;3&lt;/sup&gt;</td>
<td>6 (25.0)</td>
<td>7 (43.7)</td>
<td>16 (22.5)</td>
<td>2 (14.3)</td>
</tr>
<tr>
<td>High&lt;sup&gt;4&lt;/sup&gt;</td>
<td>3 (12.5)</td>
<td>6 (37.5)</td>
<td>38 (53.5)</td>
<td>11 (78.6)</td>
</tr>
<tr>
<td>P-ADL Participation&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dependent in ≥ 1 activity</td>
<td>7 (29.2)</td>
<td>0</td>
<td>6 (8.5)</td>
<td>0</td>
</tr>
<tr>
<td>Balance&lt;sup&gt;1&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-rated balance (bad), (n=114)</td>
<td>16 (69.6)</td>
<td>9 (56.3)</td>
<td>28 (45.2)</td>
<td>6 (46.2)</td>
</tr>
<tr>
<td>Fear of falling (yes), (n=122)</td>
<td>10 (41.7)</td>
<td>5 (31.3)</td>
<td>19 (27.9)</td>
<td>2 (14.3)</td>
</tr>
<tr>
<td>Previous falls ≥1 fall previous year, (n=122)</td>
<td>14 (58.3)</td>
<td>6 (40.0)</td>
<td>33 (47.8)</td>
<td>7 (50.0)</td>
</tr>
<tr>
<td>Physical activity&lt;sup&gt;1&lt;/sup&gt; (n=118)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>9 (37.5)</td>
<td>1 (6.3)</td>
<td>11 (15.5)</td>
<td>1 (7.4)</td>
</tr>
<tr>
<td>Nr. of chronic diseases&lt;sup&gt;5&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>12 (50.0)</td>
<td>10 (62.5)</td>
<td>35 (49.3)</td>
<td>10 (71.4)</td>
</tr>
<tr>
<td>1</td>
<td>7 (29.2)</td>
<td>5 (31.3)</td>
<td>26 (36.6)</td>
<td>3 (21.4)</td>
</tr>
<tr>
<td>≥ 2</td>
<td>5 (20.8)</td>
<td>1 (6.3)</td>
<td>10 (14.1)</td>
<td>1 (7.1)</td>
</tr>
<tr>
<td>Fall-risk-increasing drugs&lt;br&gt;(FRIDs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 FRIDs</td>
<td>4 (16.7)</td>
<td>4 (25.0)</td>
<td>13 (18.3)</td>
<td>3 (21.4)</td>
</tr>
<tr>
<td>Cardiovascular (Cvd)</td>
<td>10 (41.7)</td>
<td>4 (25.0)</td>
<td>29 (40.8)</td>
<td>5 (35.7)</td>
</tr>
<tr>
<td>Psychotropic (Psy) FRIDs</td>
<td>2 (8.3)</td>
<td>3 (18.8)</td>
<td>6 (8.4)</td>
<td>2 (14.3)</td>
</tr>
<tr>
<td>Concomitant Cvd &amp; Psy FRIDs</td>
<td>8 (33.3)</td>
<td>5 (31.3)</td>
<td>23 (32.4)</td>
<td>4 (28.6)</td>
</tr>
</tbody>
</table>

Units are expressed as number (percentage) unless otherwise stated.
<sup>1</sup>Reported performance of pre-fracture status. <sup>2</sup>Required a walking aid indoors. <sup>3</sup>Required a walking aid outdoors. <sup>4</sup>No walking aid required. <sup>5</sup>According to Charlson’s comorbidity index.
Those who described environmental fall factors (indoors) had moderate physical function but high levels of comorbidity and medication use

The two main described categories of the nature of indoor falls included physiological and environmental and are illustrated in Figure 6. When compared to those describing falls of physiological nature, those describing environmentally precipitated falls reported higher levels of physical function. Although not statistically different, these participants less frequently reported their balance as ‘bad’ (p=0.075) and appeared to have higher levels of mobility (p=0.461) and functional independence (p=0.477). Support for stronger beliefs in functional performance was frequently found in interview data where these participants commonly described collisions with furniture or tripping on cords, whilst cleaning indoors, or slipping on surfaces although often moving unhindered in the home. Despite a higher level of self-reported physical function, the group environmental had nonetheless a similar prevalence of comorbidity, fall-risk-increasing drug prescription and previous falls as those perceiving falls as caused by physiological factors (Figure 6).

**Figure 6.** Nature of the fall in relation to health characteristics for the two main indoor categories, Physiological and Environmental. *P-ADL (Personal activities of daily living)*
Those who fell outdoors in snow-free environments appeared to have poorer health than other outdoor groups

Those fracturing outdoors in snow-free environments (*Trips & slips, no snow*) appeared to have lower levels of mobility, a higher incidence of previous falls and showed tendencies towards higher prevalence of disease and use of fall-risk-increasing drugs, compared with other outdoor groups (Table 4). These participants described their falls in terms of environmental factors, often involving unsuitable footwear and/or trips on uneven paths, tree roots or curbsides which were either misjudged or not visible. Not surprisingly, those falling during more *balance challenging* activities and those describing *activity-related* falls reported the least functional limitations and appeared to be those most physically active, both indoors and outdoors.
Table 4. Nature of the fall (outdoors) in relation to health characteristics of interviewed participants (n= 401).

<table>
<thead>
<tr>
<th>Health characteristic</th>
<th>Trip/slips (snow) n=20</th>
<th>Trip/slips (no snow) n=12</th>
<th>Activity-related n=8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50–80 years</td>
<td>16 (80.0)</td>
<td>6 (50.0)</td>
<td>5 (62.5)</td>
</tr>
<tr>
<td>80+ years</td>
<td>4 (20.0)</td>
<td>6 (50.0)</td>
<td>3 (37.5)</td>
</tr>
<tr>
<td>Gender (female)</td>
<td>14 (70.0)</td>
<td>7 (58.3)</td>
<td>5 (62.5)</td>
</tr>
<tr>
<td>Mobility&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low&lt;sup&gt;3&lt;/sup&gt;</td>
<td>0</td>
<td>3 (25.0)</td>
<td>0</td>
</tr>
<tr>
<td>Moderate&lt;sup&gt;4&lt;/sup&gt;</td>
<td>5 (25.0)</td>
<td>1 (8.3)</td>
<td>2 (25.0)</td>
</tr>
<tr>
<td>High&lt;sup&gt;5&lt;/sup&gt;</td>
<td>15 (75.0)</td>
<td>8 (66.7)</td>
<td>6 (75.0)</td>
</tr>
<tr>
<td>P-ADL participation&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dependent in ≥1 activity</td>
<td>2 (15.4)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Balance&lt;sup&gt;2&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-rated balance (bad), (n=114)</td>
<td>7 (36.8)</td>
<td>6 (54.5)</td>
<td>5 (62.5)</td>
</tr>
<tr>
<td>Fear of falling (yes), (n=122)</td>
<td>4 (20.0)</td>
<td>3 (30.0)</td>
<td>0</td>
</tr>
<tr>
<td>Previous falls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥1 fall previous year, (n=122)</td>
<td>6 (30.0)</td>
<td>7 (58.3)</td>
<td>2 (25.0)</td>
</tr>
<tr>
<td>Physical activity&lt;sup&gt;2&lt;/sup&gt; (n=118)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>1 (5.3)</td>
<td>1 (8.3)</td>
<td>0</td>
</tr>
<tr>
<td>Number of chronic diseases&lt;sup&gt;6&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>15 (75.0)</td>
<td>6 (50.0)</td>
<td>3 (37.5)</td>
</tr>
<tr>
<td>1</td>
<td>5 (25.0)</td>
<td>5 (41.7)</td>
<td>4 (50.0)</td>
</tr>
<tr>
<td>≥2</td>
<td>0</td>
<td>1 (8.3)</td>
<td>1 (12.5)</td>
</tr>
<tr>
<td>Fall-risk-increasing drugs (FRIDs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 FRIDs</td>
<td>8 (40.0)</td>
<td>3 (25.0)</td>
<td>1 (12.5)</td>
</tr>
<tr>
<td>CvdFRIDs</td>
<td>7 (35.0)</td>
<td>3 (25.0)</td>
<td>6 (75.0)</td>
</tr>
<tr>
<td>PsyFRIDs</td>
<td>0</td>
<td>1 (8.3)</td>
<td>1 (12.5)</td>
</tr>
<tr>
<td>Concomitant Cvd &amp; PsyFRIDs</td>
<td>5 (25.0)</td>
<td>5 (41.7)</td>
<td>0</td>
</tr>
</tbody>
</table>

Units are expressed as number (percentage) unless otherwise stated.

<sup>1</sup>Two outdoor falls categorised as ‘Unknown’ are not illustrated in the table. <sup>2</sup> Reported performance of pre-fracture status. <sup>3</sup> Required a walking aid indoors. <sup>4</sup>Required a walking aid outdoors only. <sup>5</sup>No walking aid required. <sup>6</sup> According to Charlson’s unweighted comorbidity index.
The impact of disease on hip fracture risk (Study IV)

The prevalence of disease categories in the hip fracture and in the underlying population is shown in table 5. All disease categories were associated with an increased risk of hip fracture and highest risk ratios (RR) were observed for Circulatory system diseases (RR: 6.28, 95% CI; 5.06–7.79) and Previous injuries (RR: 5.82, 95% CI; 4.80–7.05) which had a 6-fold increase in hip fracture risk and the subgroup Previous fractures (RR: 5.12, 95% CI; 4.18–6.28) (Figure 7). An approximately 5-fold increase in risk was seen for disorders of the digestive and genitourinary systems. In absolute terms, conditions with highest impact for hip fracture occurrence per 1000 individual included; previous fracture (41/1000); previous injury (27/1000) mental disorders (26/1000), non-malignant tumors (25/1000); genitourinary and eye disorders (both 24/1000), and digestive system diseases (23/1000). No major differences were observed across disease exposures between men and women and combined estimates are therefore presented in the illustrations.

In relation to age, risk ratios for all disease categories were highest among the youngest age groups (50–69 years) and decreased in line with increasing age (Figure 8). Despite larger observed risk ratios for disease exposures among younger individuals, the impact of hip fracture in absolute terms was lower among this group as demonstrated by lower risk differences for all diseases in the younger age groups.
Table 5. Prevalence of disease categories in the both the hip fracture cohort and the source population in Uppsala county.

<table>
<thead>
<tr>
<th>Disease category</th>
<th>ICD-10 code</th>
<th>Hip fracture (n=477)</th>
<th>Source population (n=117 494)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infectious and parasitic diseases</td>
<td>A00-B99</td>
<td>106 (22.2)</td>
<td>4588 (3.8)</td>
</tr>
<tr>
<td>Malignant tumors</td>
<td>C00-C97</td>
<td>76 (15.9)</td>
<td>3867 (3.2)</td>
</tr>
<tr>
<td>Non-malignant tumors</td>
<td>D00-D48</td>
<td>79 (16.6)</td>
<td>2398 (2.0)</td>
</tr>
<tr>
<td>Diseases of blood/blood forming organs</td>
<td>D50-D89</td>
<td>89 (18.7)</td>
<td>2996 (2.5)</td>
</tr>
<tr>
<td>Endocrine, nutritional and metabolic disorders</td>
<td>E00-E90</td>
<td>162 (34.0)</td>
<td>7245 (6.0)</td>
</tr>
<tr>
<td>Mental and behavioural disorders</td>
<td>F00-F99</td>
<td>135 (28.3)</td>
<td>4013 (3.3)</td>
</tr>
<tr>
<td>Nervous system diseases</td>
<td>G00-G99</td>
<td>101 (21.2)</td>
<td>3812 (3.2)</td>
</tr>
<tr>
<td>Diseases of the eye</td>
<td>H00-H59</td>
<td>64 (13.4)</td>
<td>1850 (1.5)</td>
</tr>
<tr>
<td>Diseases of the ear</td>
<td>H60-H95</td>
<td>33 (6.9)</td>
<td>1019 (0.8)</td>
</tr>
<tr>
<td>Circulatory system diseases</td>
<td>I00-I99</td>
<td>319 (66.9)</td>
<td>12709 (10.5)</td>
</tr>
<tr>
<td>Diseases of the respiratory system</td>
<td>J00-J99</td>
<td>140 (29.4)</td>
<td>5471 (4.5)</td>
</tr>
<tr>
<td>Diseases of the digestive system</td>
<td>K00-K93</td>
<td>210 (44.0)</td>
<td>7270 (6.0)</td>
</tr>
<tr>
<td>Diseases of the skin and subcutaneous tissue</td>
<td>L00-L99</td>
<td>32 (6.7)</td>
<td>1858 (1.6)</td>
</tr>
<tr>
<td>Diseases of the musculoskeletal system /connective tissue</td>
<td>M00-M99</td>
<td>187 (39.2)</td>
<td>7316 (6.1)</td>
</tr>
<tr>
<td>Diseases of the genitourinary system</td>
<td>N00-N99</td>
<td>224 (47.0)</td>
<td>7355 (6.1)</td>
</tr>
<tr>
<td>Injury</td>
<td>S00-T98</td>
<td>246 (51.6)</td>
<td>7559 (6.2)</td>
</tr>
<tr>
<td>Fracture injury\textsuperscript{a}</td>
<td>S12-82\textsuperscript{a}</td>
<td>145 (30.4)</td>
<td>2853 (2.3)</td>
</tr>
</tbody>
</table>

\textsuperscript{a}S12/22/32/42/52/62/72/82- fracture of the neck/thorax/lumbar spine/pelvis/upper limb/lower limb/foot
Figure 7. Age- and sex-standardized risk ratios (RR’s) and risk differences (RD’s) of all disease categories (per 1000) and 95% confidence intervals (CI) of all disease categories for hip fracture.
Figure 8. Age- and sex-standardized risk ratios (RR’s) (per 1000) and 95% confidence intervals (CI) of all disease categories for hip fracture according to the age categories 50–69 years, 70–79 years and 80+ years.
Methodological Considerations

Mixed methods

This thesis, as a whole, was inspired by a mixed methods approach, which represents a primary methodological strength. The main rationale of using mixed methods is to provide a comprehensive description of the events under investigation. In the current thesis the choice of this approach was further motivated by several other important factors. Health research should support clinical decision making, and effective clinical reasoning relies on drawing from different types of knowledge.131 Additionally, health care aims to adopt a holistic and patient-centered perspective, one aspect of which involves increasing patient involvement.120 Fall-related hip fracture, like many health conditions, often involves a complex interaction of multiple contributing factors, which in turn requires a multifaceted approach of investigation.134 No single research method can explain all the facts, which motivates the choice of mixed method approaches, whereby additional insight about the research problem can be gained from integrating knowledge from different sources.159 Use of the Swedish National Patient Register as a source of data, concerning disease incidence, had the advantage of capturing health data from the entire source population. Individual identification of all hip fracture cases in our cohort also ruled out case misclassification which can occur in register-based data, when people with a history of hip fracture are falsely re-registered as new cases upon re-admission to hospital within the same year as the fracture occurred.160 Furthermore, sampling methods in cohort studies which require active participation, will on the other hand, create a bias towards the younger, healthier members of a population who are physically or cognitively capable of visiting a research center. An additional advantage of register-based data was the ability to calculate the absolute risk of disease categories on hip fracture, which better indicates the public health impact of disease, and is the estimate which should, if possible, be communicated to patients.123 A further motivation for using mixed methods is that the strength of one method can compensate for the weaknesses of another.134 The use of interviews, on the one hand, allowed us to access information concerning fall circumstances of those who were cognitively capable of recounting fall details. The use of epidemiological methods, on the other hand, enabled the inclusion of those not capable of recounting fall details due to physical and mental disease, a group commonly excluded in hip fracture research.67, 161

Relying on self-reports of fall circumstances

The majority of fall-related hip fractures occur unobserved in community settings,162 which means that accounts from those who experience falls are often the only source of this information. Nevertheless, the collection of self-
reported data regarding fall circumstances is often criticised as being potentially inaccurate, unobjective and therefore undependable as a source of information. These criticisms are grounded on proposals that older people are either not capable, due to cognitive impairment or poor recall, or not willing, due to feelings of vulnerability, to recount details of their falls. Cognitive impairment was a factor of relevance in our sample, as post-operative delirium is known to be highly prevalent among hospitalized older people who have recently undergone reparative hip fracture surgery. This factor was taken into consideration during the inclusion process to study III and less than one third of all patients with hip fracture were capable of verbally recounting details of the fall. Participants who were interviewed in study III can therefore be thought to represent those, primarily community-dwelling, people with hip fracture who have the lowest burden of physical and mental illness. The sparse representation of residential care dwellers among those interviewed (n=5) therefore reflects the high prevalence of both post-operatively acute and chronic forms of cognitive impairment in this group. This, in turn, means that we are unable to generalize findings from study III to those living in institutional care. For those who were capable of describing the fall, it should be further considered that falls can be emotive subjects which participants may have wished to distance themselves from. Criticism of older people’s fall descriptions as unobjective is complicated however for several reasons. Even if fall descriptions cannot always be considered as exact accounts of the chain of events, they still highlight important subjective beliefs concerning the nature of the fall event, which may both provide clues as to intervention strategies and may also influence how the individual reasons in relation to future fall prevention. Additionally, even in studies where falls are captured on video and are thereby objectively accounted for, analysis of these fall scenarios is still reliant on the subjective opinions of one or several, albeit qualified, individuals.

Trustworthiness

Study I and part of study III involved the collection and analysis of interview data and when ensuring scientific rigor in the treatment of text data, the use of different procedures are required. In order to achieve credibility, specific measures were taken during the various stages of data collection and analysis. During the interviews, a process of dialogical validation was used, whereby participants’ responses to certain questions were checked by posing follow-up questions such as ‘Have I understood correctly when I say that you answered that’. Detailed descriptions were also provided regarding steps in the process of both thematic analysis (study I) and qualitative content analysis (Study III). Thematic analysis and qualitative content analysis are largely similar processes, with minor differences existing mostly in relation to the terminology used to describe the analytic process. Citations from
the interviews, in both studies, have been used in the articles to allow the reader to make links between interview data and analytic interpretations. This process also aids the reader when deciding whether findings can be transferred to other settings. Furthermore, in order to ensure validity of the analytic process different forms of triangulation were used. Researcher triangulation was achieved during the analysis of interview transcripts during continual peer debriefing sessions between the authors (B. Leavy and AC Åberg). The co-author (AC Åberg) analyzed selected interviews and compared and checked the interpretation of the first author. During these sessions, sub-themes and main themes were reviewed and discrepancies discussed, so that categories would most accurately encompass and reflect the interview data.

The quality and richness of text data determines the extent to which theoretical abstraction is possible during the analysis process. Qualitative interviews are concerned with accessing the experiences and meanings people attribute to dimensions of their lives. In study I, this involved exploring general beliefs regarding PA, whereas in study III, the aim of the interviews was to explore fall events which occurred unexpectedly and instantaneously. This probably explains why many of the interviews in study III were short in length, a factor, in combination with the large number (125) of individual interviews, shaped our choice of analysis method. We considered a manifest analysis, with a lower level of theoretical abstraction, to be the most suitable method to enable an authentic representation of the participant descriptions and to avoid misdirected interpretations of the interview transcripts. Data triangulation of fall circumstances (study III) was also possible by comparing interview data with answers from closed-ended questions in questionnaire as well as medical journal data from the time of hospital admission. This allowed for a cross-checking and comparing of data from different sources which related to the same fall situation in study III.

The use of single item questions to capture health data

In light of the multifactorial nature of hip fracture occurrence, we aimed in studies II-III to investigate fall circumstances while also provide a comprehensive picture of the participants’ health and functional status. In order therefore to cover both these aspects, within a time period considered realistic for hospitalized older people who have recently undergone surgery, we chose to base our data concerning functional performance, primarily on the use of single item questions. Examples of such questions relate to physical activity and fear of falling. The disadvantage of this approach is that such questions lack sensitivity, and in the case of the dichotomous question – ‘Before your hip fracture, were you afraid of falling? (yes/no), a ‘yes’ answer does not differentiate between excessive or rational fear, or whether
fear related to the risks, or the consequences of falling.\textsuperscript{167} For this purpose, the use of standardized assessment tools such as, for example, the Falls Efficacy Scale–International,\textsuperscript{168} or the Physical Activity Scale for the Elderly,\textsuperscript{169} could have captured aspects and gradients of diversity which are not reflect-
ed in our data pertaining to these domains. On the other hand, the choice to use single item questions items is simple, less time consuming and may re-

Separating the effects of disease and medication

Confounding by indication is a factor deserving attention when interpreting the observed associations between psychotropic medications and hip fracture in study II. Psychotropic drugs are prescribed as symptom management for underlying conditions such as dementia, depression, anxiety, pain or sleeping problems, all conditions which also predispose to falls and hip fracture.\textsuperscript{56, 170} Stratification according to dementia status in study II allowed us to sepa-

Stratification according to dementia status in study II allowed us to sepa-ate the effects of fall-risk-increasing drugs from dementia on night-time falls, but the confounding effects of other health conditions cannot be ruled out. It is possible that among community-dwelling older people in our sam-
gle, depression and sleep disorders were more prevalent underlying factors for psychotropic drug prescription and could therefore have confounded the associations observed between time of the fall and medication use.\textsuperscript{171, 172} Similarly, we were unable to separate the effects of underlying disease from the effects of medications routinely prescribed to treat those diseases in Study IV. It is possible therefore that the observed absolute risk posed by mental disorders for hip fracture (26/1000) is somewhat explained by fall-

risk-increasing medications used to treat these conditions.
General Discussion

Summary of results

Being physically active in natural, outdoor environments was a recurrent motivator to physical activity among Swedish participants, regardless of their described level of activity. The importance of exercise which was functional in nature was also stressed by moderately and lesser active community-dwelling participants. Additionally, the uptake of physical activity in retirement years was described as a means of establishing a new self-identify.

In relation to hip fracture patterns, the time of day at which hip fracture occurred differed in accordance with place of residence and these 24-hour patterns may be further explained by medication use. Both residential and community-dwelling people without a dementia diagnosis, who were receiving psychotropic medication were at increased risk for hip fracture during night-time hours. Community-dwelling people with the poorest health characteristics tended to fall and fracture during changes of position indoors, and often described individual health factors as precipitators for their fall. The majority of people, nonetheless, describe their fall in terms of environmental factors, despite having relatively high levels of co-existing disease and medication use. All disease categories were seen to be positively associated with hip fracture, with cardiovascular disease and previous injury having the highest relative and absolute risks for fracture.

The role played by outdoor environments for physical activity beliefs and hip fracture patterns

Being outdoors as a motivating factor for physical activity

The importance of nature and the outdoors as a motivating factor for physical activity was apparent when subjective perceptions were explored (Study I). The attraction of outdoor environments was prominent when culture-specific motivating factors for physical activity were considered, whereby outdoor activities were valued highly especially among Swedish participants, of all activity levels. Physical activity in natural surroundings was described as therapeutic as it provided the opportunity for thought and reflection and was described as something which positively affected well-being. The added
benefits of being active in natural or ‘green’ environments, as opposed to indoor environments, are reported to primarily involve positive effects on mental health, such as decreased tension and depression, among adults in general\(^{173, 174}\) and to some extent among older adults.\(^{175}\) It also appears that older people who engage in outdoor activity achieve higher levels of PA, compared to those who do not.\(^{176}\) The skepticism towards gym-based training, which we observed among certain participants in study I, serves furthermore to highlight the pivotal role played by outdoor walks among certain older people, concerning whether they will achieve the minimum levels of PA which are required for the prevention of disease.

Outdoor environments and the risk for hip fracture

The physical activity and health patterns of people with hip fracture were somewhat reflected in the location and circumstances surrounding the fall events which led to fracture. When falls were viewed solely in relation to location (indoor/outdoor) in study II, those who fractured outdoors had the lowest levels of comorbid disease and medication use. A further breakdown of the circumstances surrounding falls in study III however, revealed the more heterogeneous health status of those who fractured outdoors. Compared to those who fractured indoors, outdoor groups generally reported higher levels of physical activity and had a lower prevalence of disease. However, we also identified a somewhat frailer group, in terms of disease burden and medication status, who also reported a higher prevalence of previous falls compared to other outdoor groups. These individuals also fell while walking under less challenging, snow-free conditions. This group of less vigorous adults, who still maintain physical activity outdoors has not previously received attention in the falls literature, possibly due to several reasons. Outdoor falls among older adults have been the focus of fewer investigations than indoor falls.\(^ {177}\) Those studies which have focused specifically on outdoor falls, have often comprised of healthy, relatively younger community-dwelling populations who may not necessarily represent those at risk for hip fracture.\(^ {177, 178}\) Other studies which dichotomized falls according to indoor/outdoor fall location have demonstrated separate risk factor profiles for indoor and outdoor falls\(^ {179-181}\) but have not considered sub-group variations among those who fall outdoors. In the literature, indoor falls are associated with indicators of poorer health and function whereas outdoor falls have been viewed as markers of a ‘vigorous’, physically active elderly group.\(^ {181, 182}\) Additionally, indoors falls are reported to predict future limitations in physical activity, whereas outdoor falls have not.\(^ {63, 179}\) In consideration of the threat of functional limitation following hip fracture\(^ {63}\) and that the group of outdoor fallers, described above, also appears to share risk factors which predispose them to future mobility limitation,\(^ {179}\) we propose that such individuals require focused efforts during hip fracture rehabilitation. Longer
follow-up physiotherapy efforts in the community, that aim to ensure a return to physical activity in outdoor environments, is one such example.

Developing walking programs for fall prevention

Walking was the most commonly described form of physical activity among the study population, many of whom stressed the importance that physical activity be functional in nature (Study I). At a national level, walking is reported as the most frequently engaged in physical activity among Swedish older adults. Similarly, walking is recommended as a way for older people to meet recommended guidelines of 150 minutes of activity per week. It is not surprising therefore that walking is the activity most frequently engaged in at the time of hip fracture. While outdoor walks provide emotional as well as physical benefits, they also place greater demands on the coordination of sensory and motoric functions as well as the need to divide attention. For older people with functional limitations, this increased demand on attentional resources can result in poorer gait performance, thus resulting in falls.

The extent to which walking is effective in falls prevention however is contested, as there is weak evidence from intervention trials for the effect of walking-based programs alone on balance gain among community-dwelling older people. The effect of walking on balance appears to be mediated by levels of frailty and fall risk, as positive effects are reported for those at low-risk for falls, whereas negative effects, such as increased fall incidence, is reported among those with a high risk for falls who enrolled in walking intervention programs. Additionally, due to the biomechanical properties of the femur, it appears that the weight-bearing effects conferred by walking are insufficient in stimulating bone formation in the area of the femoral cortex which is the weakest in a sideways fall situation. A recent meta-analysis reports some positive effects of walking on BMD at the hip, but notes that due to inconsistent results from randomized trials, walking as a single intervention may not be clinically effective at reducing fractures. Similarly, best practice guidelines for physical activity programs aimed at preventing falls state that the walking component: may not be crucial, should not be prioritized over balance training and, at worst, can increase fall rates among high-risk individuals. So, although walking is the preferred physical activity among older people, there is weak evidence for its preventive effect on falls and subsequent fractures, the threat of which increase with age.

The development of walking programs which sufficiently challenge components of balance, as well as muscle strength and weight-bearing, could help bridge the gap between walking as the most preferred exercise form among older people and that which has efficacy enough to be included in fall pre-
vention programs. Group walking programs may be an effective way of motivating lesser active older people who are often socially restricted due to mobility limitations. For less functionally impaired older people, more challenging walking programs in different outdoor terrains and inclines may be more suitable. The gradual introduction of a mixed-impact weight-bearing component, which has been reported to have positive effects on bone density levels at the femoral neck,\textsuperscript{191} may also have added benefits. Such initiatives could serve to challenge balance, and possibly bone strength, while at the same time be perceived as relevant and meaningful forms of physical activity by older people.

Patterns in fall circumstances reflect the health and functional status of people with hip fracture

Night-time falls and the use of psychotropic medication

Examination of the times at which fall-related hip fractures occurred, within different locational settings, revealed interesting findings in relation to participants’ health characteristics (Study II). We observed a higher night-time incidence of hip fracture in residential care settings, a pattern which we observed to be further associated with psychotropic medication use. This is a previously unreported observation concerning hip fracture patterns. There is support in the literature for the high levels of psychotropic drug prescription in residential care settings.\textsuperscript{192-194} This medication use is often concomitant with a high prevalence of dementia, itself the most frequent reason for admission to a care homes.\textsuperscript{195} Whereas others have linked night-time falls and cognitive impairment in psychogeriatric settings,\textsuperscript{196} we found night-time hip fractures to be associated with psychotropic medications, regardless of the presence of dementia or residential setting. This finding has implications for fracture prevention as medication prescription is a risk factor which may, in many cases, be modified. Randomized trials have demonstrated reductions in falls and improvements in muscle strength and balance when psychotropic drugs are withdrawn.\textsuperscript{197, 198} Sedatives and anti-depressants were among the most commonly prescribed fall-risk-increasing drugs at the time of hospital admission among community-dwellers in our sample (study II). Anti-depressants have been shown to negatively affect sleep patterns\textsuperscript{199} and gait patterns,\textsuperscript{200} as well as cause postural hypotension among older people, which are three possible explanations for the associations between night-time hip fracture and psychotropic drugs which we observed. Confounding by indication is also a factor for consideration in this instance, as depression, even when untreated by medication, is also associated with sleep disturbances,\textsuperscript{172} as well as delayed reactions, both of which are known risk factors for falls. These factors may in turn explain why depressive symptoms are repeatedly
associated with falls in older people, regardless of residential care setting.\textsuperscript{201} Our findings reinforce those of others, which highlight the importance of carefully weighing the potential advantages of prescribing fall-risk-increasing drugs to older people, against the known disadvantages in terms of increased risk for falls and hip fracture. This is especially relevant when prescribing psychotropic drugs for older people with existing fall risk factors such as: previous falls, mobility limitation and cognitive impairment.

Activity at the time of the fall and health status

When participants’ health was viewed in relation to the activity they were engaged in at the time of the fall, those who fell during positional change had the poorest overall health status. Studies which have measured gait parameters in older people during the sit-to-walk phase have demonstrated that those with fear of falling tend to adopt a wider step width.\textsuperscript{202} This postural adjustment along with a slower walking speed then results in a higher sideways velocity.\textsuperscript{202} Additionally, a fall in a sideways direction strongly predicts the risk of hip fracture occurrence.\textsuperscript{89} Our findings, in the light of others, highlight possible ways to tailor fall prevention for older people with functional limitations. Focusing, for example, on the assessment and training of muscle strength and power during specific locomotor tasks, such as sit-to-walk, during physiotherapy sessions could be an effective starting point. These findings also highlight the importance that physiotherapists and general practitioners ask simple questions regarding eventual symptoms which precede falls, which may provide clues as to causation. Whereas dizziness was frequently described among those who fractured indoors, an equal amount of participants described a symptomless loss of balance and in ten cases, precipitating factors for the fall remained unknown to those who had fractured. Asymptomatic orthostatic hypotension is reported to account for a larger proportion of cases of postural hypotension than the symptomatic form\textsuperscript{203} and could partly explain falls which are described as involving a symptomless loss of balance or for unknown reasons. There is also evidence that such symptoms can be caused by the effects of drugs with anti-hypertensive effects,\textsuperscript{204} which explains why certain cardiovascular medications are categorized as fall-risk-increasing drugs. Even if orthostatic hypotension may be difficult to assess or treat in the clinical setting,\textsuperscript{205} simple physical or behavioral compensatory strategies can be taught to patients who present with orthostatic intolerance and a history of falls.\textsuperscript{206} Possible techniques which oppose orthostasis and can be taught as a part of tailored fall prevention include: muscle tensing of the lower larger muscle groups, heel raises, bending forward, leg crossing and breathing exercises.\textsuperscript{206}
People in the current study who described their fall in relation to their movements or activities (activity-related) at the time of the fall had, in general, fewer functional limitations. This group also tended to explain falls in terms of their own behavior, as activity-related indoor falls often involved descriptions of hurrying or undertaking more complicated tasks within the home. It is worth noting that this group consisted entirely of female participants, so the influence of gender cannot be ruled out, as men and women have been reported to reason differently in relation to falling and fall risk.\textsuperscript{116} Explorative studies report, for example, that older women are more likely to blame themselves when describing fall events.\textsuperscript{207} Alternatively, these fall descriptions may also reflect the time spent engaging in specific tasks as women generally spend more time performing household duties even in higher ages.\textsuperscript{208} Greater fall rates have been previously reported amongst women while performing household activities,\textsuperscript{209} a factor which is often explained by the increased exposure time at risk in indoor environments. Furthermore, psychological traits such as risk-taking behavior have been identified as an independent risk factor for falls, but may be difficult to assess from self-reported behavior.\textsuperscript{210} Such factors have not been in focus in the current thesis but are relevant topics for future investigation.

Falls in outdoor environments and good perceived health

Falling outdoors is associated with good health and higher physical activity levels, both in our investigations (study II and III) and in those of others.\textsuperscript{179, 180} It may also be the case that less ‘robust’ older people who fall and fracture outdoors have good perceived health and thereby attribute falls to environmental factors. This is a possible interpretation as to why those who fell outdoors in less challenging (snow-free) circumstances explained their falls in terms of the environment and not in terms of their health or function, despite their relatively high levels of disease, medications and previous falls (Study III). Not only has physical activity in natural environments been associated with emotional benefits such as reduced tension and depression,\textsuperscript{173} but also been connected with better perceived health in general populations.\textsuperscript{174} In turn, older people with good perceived health have also been reported as being less likely to perceive themselves as being at risk of falls.\textsuperscript{116} People who were capable of engaging in outdoor walks may therefore have better perceived health, regardless of having a similar burden of co-existing disease and drug prescription as those whose fall occurred indoors.

Gender-related differences

It is also possible that gender differences in fall perceptions partly explained why those who fractured outdoors under less challenging circumstances did...
not describe their fall in terms of health factors. This group comprised of a relatively larger proportion of male participants than other groups, and others have shown that older men are more likely to have a low perceived risk of falling and are less likely to ‘self-blame’ in relation to falls than women are. The greater propensity for men to fall outdoors, which we observed, has also been previously reported. This pattern may, like that of female participants falling during household activities, be explained by increased exposure time in outdoor environments. Gender differences have however not been in focus in the current thesis, and subgroup analysis of fall patterns in relation to health status, may have been hindered by the small total number of men in study III. Nonetheless, we did observe (Study IV) that in relation to the disease categories with the highest impact on hip fracture risk (Previous injury and Circulatory disease), the relative risks were somewhat higher for male subjects whereas the absolute risks were higher in both cases among females.

The impact of co-existing disease on hip fracture and physical activity beliefs

Disease as a predisposing risk factor for hip fracture

Investigation of fall descriptions (study III) highlighted ways in which symptoms of disease acted as precipitating factors in the acute onset of fall-related hip fractures. By comparing the disease history of the entire hip fracture cohort to that of the source population in the region (study IV), we could calculate estimates for co-existing disease as predisposing risk factors for hip fracture. We observed positive associations between all disease categories and hip fracture, a pattern supported by those who have investigated a smaller range of disease exposures. In the literature, a greater focus has been placed on calculating the relative risks posed by medication use for falls and hip fractures, than that posed by underlying disease. This is despite evidence that co-existing disease may pose a stronger population proportionate attributable risk for falls, than medications do. Additionally, inclusion of disease-related data has been shown to substantially improve the predictive ability of tools developed to identify individuals at high risk for hip fracture. Nonetheless, it should also be considered that the impact of co-existing disease may be reported indirectly when the exposures under investigation include functional impairments, such as gait or balance, and the risk they pose for falls. Nevertheless, it is recognized that adults with a high prevalence of co-existing disease, more frequently experience falls and hip fracture and that an overlap exists between comorbid disease, disability and frailty in older populations. It is however, uncommon that the separate effects of underlying disease categories for hip fracture are reported, and this
knowledge should serve as a first step in identifying those who are at high risk and deserve further assessment.

Previous injury as a risk factor for hip fracture

After cardiovascular disease, previous injury and the sub-group previous fracture were the disease categories with the highest relative and absolute risks for hip fracture. Having a history of fracture is a well-established predictive factor for future hip fracture, and is a factor which may signal reduced bone mineral density as well as an increased tendency to fall. The category ‘Previous injury’ can be considered to largely incorporate prior falls which required hospitalization, as the vast majority of injury-related hospitalizations among older people are fall-related. That previous falls are predictive of future falls is well supported in the literature, as well as implemented in clinical practice where questions relating to falls are incorporated in several formal fall risk assessment tools, such as the Downton fall risk index, STRATIFY, and the Fall Risk Assessment Tool. Additionally, the Swedish Association of Local Authorities recommends that, upon admission to hospital environments, all people aged 65 years and older be asked whether they have fallen in the previous year, as one of the two screening questions which initially assess fall risk.

Perceptions of the relevance of previous falls

Whether older adults share the understandings of researchers and clinicians regarding the relevance of previous falls however is unclear. Approximately half of all participants who were interviewed (study III) had experienced a fall in the year previous to fracture. Nevertheless, a relatively smaller proportion of participants answered ‘yes’ to having had a fear of falling prior to the fracture and this was especially the case among certain groups who fractured outdoors. It has been previously reported that community-dwelling older people perceive their risk of falls as low, in spite of having a history of falls. Although we do not have data concerning the extent to which previous falls were followed up in our cohort, others report that older adults tend not to seek medical help for falls as 75–80% of non-injurious falls go unreported to health professionals. When help-seeking behaviors among older people have been explored, it appears that previous falls are often rationalized as not being a legitimate enough reason to warrant seeking medical help. This is in accordance with evidence that older people are less likely to seek medical help or engage in preventive behavior, when they perceive that symptoms are a normal part of aging. As we observed (study III), even when falls have severe consequences, in the majority of cases, people do not perceive these events as being related to personal health factors, which may further explain why seeking medical advice for non-
injurious falls is considered unnecessary. Another reason for concern is that not communicating about falls also coincides with activity curtailment and older people commonly describe avoiding future falls by ‘taking care’, a precaution which often involves a level of physical activity avoidance. Our findings, in light of those of others, highlight the importance that health professionals working with older people include questions pertaining to prior falls when recording health details, as this information may not be considered relevant on the part of the older person. Charting previous falls and including fall incidence in the follow-up assessments of the effects of rehabilitation or medical treatments should be given priority among physiotherapists, nurses and doctors working in primary and community care settings. Such approaches will also help to convey the perspective that falls in later life are often symptomatic of underlying conditions which can be treated, and not an inevitable consequence of ageing, which is a commonly held belief among those who fall and was often expressed by participants during the interviews in study III.

The impact of cardiovascular and other diseases

We observed a relative risk of 6.28 (95% CI; 5.06–7.79) for circulatory diseases, which incorporates the combined effects of hypertensive, heart and cerebrovascular diseases. Others have reported relative risk increases for stroke ranging between 2– and 12–fold, and for heart failure ranging between 1.3–3 Risk ratio/Hazard ratio increases, dependent on age, sex and time since disease onset. Functional impairments caused by stroke increase the propensity for falls, and for fall impact on the paretic side where the bone density of the femoral neck is often compromised due to reduced weight-bearing capacity on the hemiplegic leg. Cardiovascular conditions such as congestive heart failure or ischaemic heart disease, which are captured well by register data, were prevalent in approximately one fifth of subjects (according to medical journal data) in Study II. The circulatory effects of heart disease, or of the drugs which treat disease, on cerebral perfusion include for example postural hypotension, which was reported most frequently by those who fractured indoors in study III.

Other diseases categories such as genitourinary and digestive conditions were highly prevalent among people with hip fracture and posed a similar absolute risk (approximately 22/1000 individuals) as that posed by cardiovascular diseases, the most prevalent of all diseases. Urinary incontinence is a previously established risk factor for falls, but often overlooked when predisposing factors for hip fracture are investigated. Previous investigations of the impact of urinary incontinence on fractures, have focused on community-dwelling women and report lower risk estimates in relation to ‘non spine’ fractures (Relative hazard:1.34, 95% CI;1.06–1.69)
and hip fractures (RR: 2.42, 95% CI: 1.23–4.74). The higher risk estimates reported in our study may reflect our strict population-based design which served to highlight conditions more prevalent among older, frailer individuals in residential care facilities, a group often excluded in epidemiological studies which base risk calculations on community-dwelling samples. Urinary incontinence is defined as a geriatric syndrome which, like falling, is a condition involving the accumulation of impairments in multiple bodily systems.\(^2\)\(^{242}\) For these reasons falls and urinary incontinence share many predisposing risk factors such as impairments in mobility, cognition and medication use and depression.\(^2\)\(^,\)\(^{242}\)

**Perceptions of disease in relation to falls and physical activity**

In terms of participant perceptions (Study III), the presence of disease was, in the majority of cases, not discussed in relation to the occurrence of the fall which led to hip fracture. Interestingly, that medication could have potentially contributed to the fall event was not either discussed by any participant during the interviews. It was only in cases of indoor falls when obvious symptoms such as dizziness or joint pain were experienced that co-existing conditions, such as low blood pressure and arthritis, were discussed as precipitating factors. We also observed that those who had no explanation for their fall had a high prevalence of underlying disease, as well as previous falls. It has been reported that the transient nature of certain cardiovascular conditions, such as postural hypotension and syncope, can be methodologically difficult to capture in study trials.\(^78\)\(^,\)\(^{243}\) Our findings lend further support to these observations, as those who described unexplained falls, often in relation to positional change, did not discuss underlying health conditions as a potential factor in fall causation. This in turn may explain conflicting evidence concerning the impact of postural hypotension or drop attacks on falls and hip fracture. Encouraging older adults, especially those with repeated and unexplained falls, to reflect upon potential contributory factors for the fall may itself be a first step in fall prevention. Although rarely investigated, one study has shown that beliefs about fall causation are predictive of functional outcome following the fracture.\(^{244}\) Another study, which performed follow-up interviews to detect how fall beliefs changed over time, report that older people who reflected and aimed to understand why they fell also developed strategies to prevent falls, whereas those who neither reflected or understood why their fall occurred went on to restrict their activities over time.\(^235\)

In relation to physical activity perceptions, there was diversity in the way in which symptoms of disease were perceived as barriers or motivating factors. Whereas disease symptoms such as joint pain or breathlessness caused the cessation or reduction of certain physical activities among lesser active par-
participants; active people, on the other hand, interpreted similar symptoms as a motivating factor to stay physically active. As is the case with help-seeking behaviours previously described, beliefs about aging have also been shown to be associated with physical activity engagement in later life. Interestingly, participants in study I, regardless of physical activity level, did not discuss the avoidance of disease as a motivating factor to being physically active. This finding is once again a reminder that those promoting exercise in community-settings will be better served to focus on positive messages which appeal to older people’s desire to remain independent as opposed to those focusing on risk avoidance.
Main Conclusions

Exposure to natural, outdoor environments is an important motivating factor for physical activity among Swedish older adults, regardless of their described level of activity. Physical activity which is functional in nature is that perceived as most meaningful to certain groups of older people and the uptake of physical activity in retirement years can provide a way of establishing a new self-identity and adapt to lifestyle changes (Study I).

People living in residential care facilities are more likely to fracture their hip during night-time hours, unlike community-dwelling people, who experience a daytime peak in hip fracture occurrence. Hip fractures which occur during night-time hours also appear to be associated with the use of psychotropic medications, regardless of the presence of dementia, or whether the person lives in residential care or in the community. Community-dwelling people with poor health and function may be at greatest risk for hip fractures during positional changes indoors, such as sit-to-walk, and these people also perceive their fracture to be precipitated by poor health. The majority of people with hip fracture however, describe their falls as being precipitated by environmental factors, despite having relatively high levels of co-existing disease and medication use (Study II and III).

All disease categories appear to be positively associated with hip fracture, and cardiovascular disease and previous injury pose the highest relative and absolute risks for fracture. Less prevalent conditions however, such as genitourinary, digestive and eye diseases pose absolute risks of a similar impact to that posed by cardiovascular diseases (Study IV).

The use of a mixed method approach to investigate the multiple perspectives of hip fracture occurrence can reveal possible contributory factors for these events and ways in which they may interact. Such knowledge may in turn inform the tailoring of fall prevention strategies for those at risk.
Clinical implications

Our findings emphasise that knowledge of the context of hip fracture events is essential to understanding the problem. In the clinical setting, posing question concerning the fall circumstances of older people need not be time or resource consuming, and may reveal patterns relating to health and function which contributed to the fall. Similarly, taking people’s fall perceptions into consideration may also be a key factor in understanding how best to help them avoid the next potential fall event. That those who live in residential care are more prone to hip fracture during night-time hours, may signal important structural aspects, such as staffing levels and medication routines, which are akin to modification in these settings. Medication prescription is a modifiable risk factor for falls and psychotropic drug withdrawal has been shown to be effective in falls prevention.\(^{197}\) This strategy may also be especially important among frail nursing home dwellers, where evidence is still lacking for the effectiveness of exercise interventions in falls reduction.\(^{246}\) Additionally, higher staffing levels and education appear to be related to lower levels of psychotropic drug prescription in nursing homes.\(^{247}\) which is a factor of relevance in the context of findings in this thesis. Community-dwelling people with functional limitations also require information regarding the increased fall risks of drugs such as anti-depressants or sedatives, so that they can make informed decisions regarding their potential benefits and dangers.

People hospitalized with hip fracture, and older people who fall recurrently are a heterogonous group, who therefore require different caring pathways in terms of rehabilitation and fall prevention. Among community-dwelling people with frail health, the most effective starting point for rehabilitation or fall prevention may involve focused strength and balance training, aimed at specifically improving capacity during positional transfers. A recent study which incorporated graded tasks such as sit-to-stand reports improvements in strength and balance among older subjects.\(^{248}\) High-intensity functional exercises have also been reported to prevent functional decline in residential care settings among people with dementia.\(^{249}\)
Most importantly, health care professionals working with older adults need to systematically document fall histories and apply follow-up strategies concerning falls, as this information may not be considered relevant by the person who has experienced them.

Although not investigated in direct relation to each other in the current thesis, findings regarding physical activity perceptions in study I are applicable to the promotion of exercise as a means of fall risk reduction. Community-dwellers in study I did not articulate that it was avoidance of disease or negative health outcomes, that motivated them to stay physically active. These tendencies are also reflected in reports that messages concerning fall avoidance are less attractive to those ‘at-risk’, than messages which appeal to the desire to remain strong and independent. Staying healthy and strong is a message which should be kept in mind by health professionals who work with older people. Similarly, older people who are clinically defined as being ‘at-risk’ may neither perceive themselves as being at risk, nor consider risk avoidance to have precedence over maintaining functional independence. Indeed exposing themselves to risk may be an important component of good perceived health.

Exercise promotion amongst those at the transitional pre-retirement stage, focusing on functional exercise and challenging walking programs in outdoor environments, are strategies which could appeal to older populations. If walking programs can be developed that sufficiently challenge balance, strength and endurance, this could bridge the gap between walking as the exercise of choice among older people and that which has adequate efficacy for inclusion in fall prevention programs. The way in which older adults perceive PA or falls may differ from the opinions of professionals working in PA promotion or falls prevention. For the older person, physical health benefits may, for example, not be the primary motivator to staying physically active and maintaining independence may be more important than evaluating the risk for falls in certain situations. Nevertheless, a merging of knowledge from both perspectives should benefit the development of effective strategies to promote physical activity and prevent fall-related hip fracture, which also appeal to older adults.
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