Falls in Older People in Geriatric Care Settings

Predisposing and Precipitating Factors

By

Kristina Kallin

Umeå 2004
To my dear parents
Barbro and Nils
and
my beloved daughters
Johanna and Elin
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ABSTRACT

FALLS IN OLDER PEOPLE IN GERIATRIC CARE SETTINGS
PREDISPOSING AND PRECIPITATING FACTORS

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Falls and their consequences are a major health problem in the older population, increasing their immobility, morbidity and mortality. This thesis focuses on older people living in geriatric care settings, frail older people who are most prone to suffer falls. The aim was to study predisposing and precipitating factors associated with falls in older people with or without cognitive impairment.

In a cross-sectional study with a one-year prospective follow-up for falls 63% of the 83 residents suffered 163 falls and 65% of the fallers fell more than once. The antidepressants selective serotonine reuptake inhibitors (SSRIs), impaired vision and being unable to use stairs independently were the factors most strongly associated with sustaining falls. Acute diseases were judged to have precipitated 32% of the falls and drug side effects 9%.

In another cross-sectional study with a one-year follow-up for falls, including 199 residents, previous falls and treatment with antidepressants (mainly SSRIs) were found to be the most important predisposing factor for falls. Acute disease was judged to be the precipitating factor alone or in combination, in 39% of the falls, medical drugs in 8%, external factors such as obstacles in 8% and other conditions both related to the individual and the environment, such as misinterpretation, misuse of roller walkers or mistakes made by the staff were judged to have precipitated 17% of the falls.

In a population-based cross-sectional study including 3604 residents in geriatric care settings more than 8% sustained a fall at least once during the preceding week. A history of falls, the ability to get up from a chair, the need for a helper when walking, pain, cognitive impairment, use of neuroleptics and use of antidepressants were all associated with falls in multivariate analyses.

In the subgroup of people with cognitive impairment (2008 residents) more than 9% had sustained a fall at least once during the preceding week. As for the whole population, being able to get up from a chair, previous falls, needing a helper when walking with the addition of hyperactive symptoms were the factors independently associated with falls.
In a study with a one-year prospective follow up for falls, including 439 residents in residential care facilities, 63% sustained 1354 falls, corresponding to an incidence rate of 3.5 falls / person year. Thirty-three percent of the falls and 37% of the injurious falls occurred during the night (9pm-6am). There were significantly higher fall rates in the evening and in January, April, May, November and December. There were no associations between fall rates and any of the weather parameters studied.

In conclusion falls and fall-related injuries in older people in geriatric care settings are common. Both predisposing and precipitating factors contribute to the risk of falling. Addressing precipitating factors for falls seems to be important in an individualised preventive strategy among older people in geriatric care settings.

Keywords: accidental falls, risk factors, older people, residential facilities, geriatric care, cognition, drug therapy, wounds and injuries, geriatric psychiatry, meteorological factors.
SVENSK SAMMANFATTNING

Fall och deras konsekvenser hos äldre människor är ett stort hälsoproblem som leder till minskad fysisk aktivitet, ökad sjuklighet och dödlighet. Den här avhandlingen fokuserar på äldre boende på olika äldreboenden, sköna äldre som har störst risk att falla. Syftet var att studera både faktorer som ökar risken för fall och faktorer som utlöser fall bland äldre med eller utan nedsatt kognition.

I en tvärsnittsstudie med ett års uppföljning av fall ådrog sig 63% av de 83 personerna boende på ett servicehus 163 fall och 65% av dem som föll, föll mer än en gång. De antidepressiva läkemedlen selektiva serotonin-återupptagshämmare (SSRI), nedsatt syn och att inte kunna gå oberoende i trappor var de faktorer som var starkast associerade med att falla. Akut sjukdom bedömdes ha utlöst 32% och läkemedelsbiverkningar 9% av fallen.

I en annan tvärsnittsstudie med ett års uppföljning av fall, som inkluderade 199 äldre boende på servicehus, var tidigare fall och behandling med antidepressiv medicinering (fTa SSRI) de viktigaste predisponerande faktorerna för fall. I 39% av fallen bedömdes akut sjukdom vara utlösende faktor enskilt eller i kombination med andra faktorer och läkemedelsbehandling i 8% av fallen. Yttre orsaker, t.ex. hinder bedömdes vara utlösende faktorer i 8% av fallen och i 17% andra omständigheter, både relaterade till individens och omgivningen, t.ex. missbedömningar, felanvändning av rollator, eller misstag gjorda av personal.

I en populationsstudie inkluderande 3604 personer i olika vård- och boendeformer för äldre hade mer än 8% ådragit sig minst ett fall den senaste veckan. De faktorer som var starkast associerade med att falla var tidigare fall, att resa sig från en stol, att behöva en följeslagare vid gång, smärta, nedsatt kognition samt behandling med neuroleptika och behandling med antidepressiva läkemedel.

Bland äldre med kognitiv nedsättning (2008 boende) hade mer än 9% fallit minst en gång senaste veckan. Förmåga att resa sig från en stol, tidigare fall, att behöva ledsagare vid gång samt hyperaktiva symptom var de faktorer som var starkast associerade med att falla.

I en studie med en ett-årig uppföljning av fall, som inkluderade 439 äldre människor på 9 olika servicehus ådrog sig 63% totalt 1354 fall, vilket motsvarar en fallincidens på 3.5 fall/personår. 33% av fallen och 37% av skadefallen inträffade under natten (kl.21.00-06.00). Fallförekomsten var signifikant högre på kvällen och i januari, april, maj, november och i
december. En hypotes var att väder och/eller förändringar av vädret skulle kunna öka fallrisken hos äldre, men något sådant samband gick inte att påvisa.

Avhandlingens slutsats är att fall och fallrelaterade skador bland äldre i särskilda boenden är ett stort folkhälsoproblem. För att kunna förhindra fall måste man upptäcka, förebygga och behandla/åtgärda både predisponerande och utlösande faktorer.
<table>
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<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>ACE</td>
<td>Angiotensin Converting Enzyme</td>
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<tr>
<td>ADL</td>
<td>Activities of Daily Living</td>
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<td>AIS</td>
<td>Abbreviated Injury Scale</td>
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<td>BMI</td>
<td>Body Mass Index</td>
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<td>CI</td>
<td>Confidence Interval</td>
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<tr>
<td>DSM-III-R</td>
<td>Diagnostic and Statistical Manual of Mental Disorders, Third Edition-Revised</td>
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<td>DSM-IV</td>
<td>Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition</td>
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<tr>
<td>FICSIT</td>
<td>Frailty and Injuries: Cooperative Studies of Intervention Techniques</td>
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<td>FR</td>
<td>Functional Reach</td>
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<tr>
<td>ICD 10</td>
<td>The International Classification of Diseases and Related Health Problems, Tenth Revision</td>
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<td>MADRS</td>
<td>Montgomery-Åsberg Depression Rating Scale</td>
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<td>MAIS</td>
<td>Most serious injury connected with the incident according to the AIS</td>
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<td>Md</td>
<td>Median</td>
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<td>MDDAS</td>
<td>Multi-Dimensional Dementia Assessment Scale</td>
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<td>MIF chart</td>
<td>Mobility Interaction Fall chart</td>
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<td>MMSE</td>
<td>Mini-Mental State Examination</td>
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<td>NSAID</td>
<td>Non-Steroidal Anti-Inflammatory Drugs</td>
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<td>PPA</td>
<td>The Physiological Profile Assessment</td>
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<td>PROFET</td>
<td>The prevention of falls in the elderly trial</td>
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<td>PY</td>
<td>Person Years</td>
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<td>SD</td>
<td>Standard Deviation</td>
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<td>SNRIs</td>
<td>Serotonin and noradrenalin reuptake inhibitors</td>
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<td>SSRIs</td>
<td>Selective serotonin reuptake inhibitors</td>
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<td>STRATIFY</td>
<td>St Thomas's risk assessment tool in falling elderly inpatients</td>
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<td>TCAs</td>
<td>Tricyclic antidepressants</td>
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<td>TUG</td>
<td>Timed Up and Go</td>
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LIST OF ORIGINAL PAPERS

The thesis is based on the following papers, which will be referred to in the text by their Roman numerals:


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INTRODUCTION

Older people have often been neglected in research and in healthcare and scientific knowledge about medical treatment, for example, is therefore limited (1). Ageism, a prejudice against older people, consists of a negative bias or stereotypical attitude toward ageing and the aged and is widespread in the health sector and society at large (2, 3). Even if biological ageing means a reduced reserve capacity, a nihilistic attitude towards health problems in older people could not be seen as acceptable. On the contrary, a reduced reserve capacity means that minor strains and health complications may result in serious diseases and functional decline in older people. Falling, for example, has been seen as an almost natural unavoidable part of growing old despite the fact that falling results in increased morbidity and mortality in older people. Ageism is maintained primarily in the form of negative stereotypes and myths concerning the older adult and is also reflected in the language (4). The British Geriatric Society has recommended the use of the concept “older people” instead of “elderly” to counteract ageism and these recommendations are, for example, clearly outlined in the “Instructions to authors” for the journal Age and Ageing.

The world’s population is growing older and people aged 60 years or older comprise 10% of that population, and this figure will double within the next 50 years. In Sweden, 22% of the total population are aged 60 years or older and of these 10% are aged 85 years or older (5). In 2050 these proportions will have increased by approximately two thirds (6). Demands for healthcare and services will be greater in the future, since the prevalence of diseases and impairments increases with advanced age. It is therefore of great importance to expand our knowledge about health and threats to good health in older people.

One of the greatest threats in older age is the risk of sustaining falls. Fall accidents occur at all ages (7), but in older people they occur in every day life situations, that were safe earlier in life. Sustaining falls in old age is the most common form of accident; the incidence exceeds that for traffic accidents and occupational accidents in Sweden, and is the most common cause of accidental death in the Swedish population (8).

The consequences of falls are much more serious in older people since they are more susceptible to injuries than younger people are, due to their frailty (9). Approximately 19 000 older people sustain a hip fracture and at least 1 000 die each year, in Sweden, because of a fall accident (7, 8, 10-12). Falls are one of the most common causes of death in older people in Sweden, after deaths caused by cardiovascular diseases and malignancies (13). Furthermore, falls often lead to restricted mobility, both functional limitations and a self-
imposed decline because of fear of falling and are associated with an increased risk of placement in institutional care (14-16).

Falling has often been attributed to the environment, but the cause of falls in older people is to a great extent multifactorial – combinations of predisposing and precipitating factors, as well as of external and internal factors related to the environment and the individual respectively (17). In a given situation, the fall risk will depend on the interactions between the individual, the activity or task performed, and the environment in which it is performed (18). Knowledge of this has been developed during the last 2-3 decades, starting with the longitudinal studies of falls carried out by Gryfe et al and Sehested & Severin-Nielsen in the 70s (19, 20). Apart from focusing on fall incidence and risk factors for falls, several studies in the past ten years have been conducted with the aim of evaluating fall prevention programs and whether falls can be reduced in some populations through preventive efforts (21-23). If we can reduce the incidence of falls, we will also reduce injuries (24, 25).

**DEFINITIONS OF FALLS, FALLERS AND FALL-RELATED INJURIES**

In the literature there are various definitions of falls. The Kellog International Group on the Prevention of Falls defined a fall as; "An event which results in a person coming to rest inadvertently on the ground or floor or other lower level and other than as a consequence of the following: sustaining a violent blow; loss of consciousness; sudden onset of paralysis, as in stroke; or an epileptic seizure" and this definition has influenced subsequent research (26). Falls occurring due to loss of consciousness (syncope or seizure) or sudden paralysis were defined as ‘syncopal falls’ by Nevitt (27). Authors have often failed to report whether syncopal falls have been included or excluded in their research, but a tendency is for syncopal falls to have been included in studies of older people living in institutions and excluded in studies of those living in the community. Kenny et al defined a non-accidental fall as coming to rest on the ground or other level, and which was unexplained and not due to an accidental event such as a slip or trip, or not attributable to a medical cause such as epilepsy, stroke, alcohol excess, orthostatic hypotension, other bradyarrhythmias etc. (28, 29). The definition that is consistent with the International Classification of Diseases and Related Health Problems, Tenth Revision (ICD 10) states that a “fall is an unexpected event where a person falls to the ground from an upper level or the same level” (30). Jensen et al defined a fall as “an event in which the resident unintentionally came to rest on the floor, regardless of
whether an injury was sustained”. This definition also includes falls resulting from an acute illness or epileptic seizure and incidents that resulted in a person’s falling and being found on the floor by staff or another person (31), but not those where the faller came to rest or tumbled against a piece of furniture, a wall or another structure. Jensens’ definition of a fall is the one used in this thesis. Small variations in definitions may be crucial for the results and evaluation of the results of previous studies can be somewhat problematic, as is highlighted in one of the FICSIT studies (Frailty and Injuries: Cooperative Studies of Intervention Techniques), where two definitions are used (32).

A faller is usually defined as someone who has fallen at least once over a set period of time, usually one year or six months, whereas a recurrent faller has fallen twice or more during the time period (27, 33). Some authors define a faller as someone who has had at least two falls and a recurrent faller as someone who has experienced three or more falls over a period of time. The second definition has been formulated based on findings which assume that the “once only faller” has characteristics more closely related to non-fallers than to “twice or more fallers” (34). One fall could be a coincidence, while falls in the recurrent faller represent more of a pattern (27, 33). The first definition of a faller and a recurrent faller is used in this thesis.

Injuries resulting from falls are often classified as minor, major or serious and each researcher defines what is included in each group. Another scoring of injuries used in research into falls (31) is the Abbreviated Injury Scale (AIS), which is an anatomical scoring system first introduced in 1969 and revised in 1990 (35). The scale ranks injuries 1 to 6, with 1 being minor (including superficial wounds), 2 moderate (including for example major lacerations and wrist fractures), 3 serious (including major fractures such as hip fractures) 4 severe, 5 critical and 6 a fatal injury (such as decapitation). Fall injuries in older people are seldom ranked higher than 3. MAIS indicates the maximum injury connected with the incident according to AIS (35).

**Epidemiology**

One third of community–living, generally healthier, people over 65 years and 50% of those over 80 years fall each year (36-44). Falls are even more prevalent among people in institutional care where as many as two thirds fall every year (43, 45, 46). Recurrent falls are estimated to happen in 12-29% of community-living older people (39, 42), in 40% of people...

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living in institutions (46, 47) and in as much as 57% of ambulatory people in long-term institutional care (48). The incidence of injurious falls depends on definition, which varies among studies, and the accuracy of the fall registration. An under-reporting of falls will thus result in higher injury rates. Injuries are reported to occur in up to half of the falls (44, 46, 49, 50). Approximately 6-15% of the falls result in serious or major injuries such as fractures, head injuries and serious soft tissue injuries, and up to 30% of the fallers suffer serious injuries (45, 46, 48, 49, 51-53). The risk of injuries has been reported to be higher in institutional falls (15, 48) related to a higher prevalence of comorbidity and age-related decline. Fractures occur in 3-4% of the accidental falls (15, 54) and 7-9% of the fallers sustain fractures (46, 54, 55). Women more often sustain injuries in falls than men (48, 52, 56, 57, 58), and women are also more likely to sustain fractures (50, 59, 60).

Seventy-nine percent of all injuries in older people who were treated in an emergency department were fall related (61). Fall injuries accounted for 54% of all injuries and for 75% of all hospitalizations for injury, in people aged 65 years and older (56). About 35-45% of the injurious falls in older people require hospitalisation and the hospitalisation rate increases with increasing age (9, 59, 62). Hip fractures, the most common serious injuries caused by falls, considerably increase the risk of permanent institutionalization and also of mortality. After a hip fracture, approximately every second person never becomes a functional walker again, 20% will die within 6 months and 29% will become institutionalized (63, 64). In addition to sustaining fall-related injuries, the inability to get up without assistance after a fall may lead to serious morbidity, such as hypothermia, dehydration, bronchopneumonia and pressure sores. Almost half of community living fallers require help getting up after a fall and about 10% of falls result in lying on the floor or ground longer than 30-60 minutes (65, 66).

Falls are associated with increased healthcare costs and this relation increases with the frequency and the severity of falls (67). The cost of injuries also increases with the advancing age of the faller (9, 68). Falls among people aged 60 years and older have been estimated to account for one third of the total cost of medical treatment for all injuries in the Swedish population (69). Almost all distal forearm and hip fractures (93% and 97% respectively) are fall-induced (61). In 1992 the increased costs, due to a hip fracture, for the first year after the fracture were sustained have been estimated at about 22 000 US dollar (USD) in Sweden, including both hospital costs and the costs of referrals to health services within the municipality (70). In 2000, 40 700 older people sustained injuries from a fall leading to inpatient hospital care for at least one day, in Sweden (12). The direct cost for injuries caused
by falls in older people was estimated at almost 4.8 thousand of million Swedish crown (SEK) during the year 2000, and that cost is estimated to increase by 65% to almost 8 thousand million SEK by the year 2035, based on the assumption that the proportion of older people demanding hospital care after a fall will remain unchanged (12). However, fall-induced injuries are increasing more rapidly than can be accounted for by the increase in the older population (71, 72).

In addition to injuries, fear of falling is common after falls. About one third of people over 60 years old develop a fear of falling after a fall incident (73) and half of those over 75 (39). In 1/4 of older people falls caused them to limit their activities (74). Fear of falling has been shown to be greater in women, to increase with age and to be associated with reduced satisfaction with life, increased frailty and depressed mood (75, 76). Among older women who have exceeded average life expectancy, quality of life is profoundly threatened by falls and hip fractures, 80 % of them would rather be dead than experience the loss of independence and quality of life that results from a bad hip fracture and subsequent admission to a nursing home (77).

The fall incidence seem to vary over time. Monthly, but no weekly, variations of indoor falls have been seen in older people in residential care, although not consistently over a three-year period (53). The fall incidence has been shown to be high, often highest in the evenings, in institutions (43, 46, 53) and in the afternoon in community-living older people (78). Most studies reveal that there are seasonal variations of incidence rates of hip and forearm fractures (79-81), which could indicate a seasonal variation in fall rates.

**RISK FACTORS FOR FALLS**

Risk factors for falls may well be described as consisting of two parts; predisposing and precipitating factors, where predisposing factors correspond to chronic and precipitating factors to acute risk factors. Factors related to the subject leading to a predisposition to fall (demographic, physical and medical factors) are predisposing factors that, especially in combination, force the older person closer to the threshold of falls. The risk of falling increases dramatically as the number of predisposing factors increases (15, 27, 39, 82-84). The circumstances at the time of the fall, for example acute diseases, type of activity in progress and environmental circumstances, are factors precipitating the actual fall, pushing the older person over the fall threshold and can be defined as precipitating factors. One can
easily imagine that the more predisposing factors that are present, the more the threshold for sustaining a fall is lowered and fairly small changes in medical status and/or environment may precipitate a fall.

Factors associated with falls have been studied both retrospectively and prospectively. Prospectively is the preferred method since older people have difficulties recalling earlier falls (85). Therefore a common method used in studies of associations between probable predisposing factors and falls is to assess, for example, mobility functions, diseases and medication use followed by prospective monitoring of the occurrence of falls most often for six or twelve months. Factors precipitating falls should be studied in close connection with the fall event to make it possible to judge what actual circumstances contributed or precipitated the fall (e.g. acute disease, environmental obstacles) but this demands more resources and is less frequently performed. Similar strategies are often used in the analyses of occupational and traffic injuries (86, 87).

PREDISPOSING FACTORS

A wide range of factors have been identified as being associated with falls, some are only occasionally reported, but some have repeatedly been found to be important risk factors (88). The predisposing risk factors cover many domains and usually have an accumulated effect on the risk of falling.

Recurrent fallers have often been studied with reference to the assumption that single falls are less predictable and may be due to accidents and overwhelming incidents (27, 33, 49, 89). The factors today commonly accepted as predisposing factors are given in no order of precedence:

**Age and sex**

The risk of falling increases steeply with older age (27, 36-39, 43, 88, 90-93). Most studies indicate that women fall more often (19, 36, 38, 41-43, 94, 95) and are far more likely to incur injuries (48, 52, 56, 57, 58) and fractures (41, 52, 58-60) when they fall. Some studies have not found any sex differences (27, 39, 78, 91). In some studies the sex differences are shown to level out with advancing age (38, 42, 43). Among the oldest people in institutions some studies indicate that men fall more frequently than women (43, 54).
Previous falls
A history of falls has been shown to be one of the factors most strongly associated with falls (27, 40, 92, 96, 97).

Impaired gait and balance
Gait or balance disorders are among the most common predisposing factors for falls in studies of older people living in institutions (15, 96-98), but also for falls in community-living older people (27, 34, 39, 40, 42, 88, 99-101). Good balance is a complex skill and a prerequisite for many daily tasks such as walking and transferring. With increased age, the ability to balance decreases (102, 103).

Impaired vision
Several reports have indicated impaired vision as a predisposing factor for falls (15, 36, 37, 39, 40, 88, 104, 105).

Impaired cognition and dementia
Irrespective of type of dwelling, impaired cognition and dementia are clearly associated with an increased risk of falling (37, 39, 106-108). One fifth of older people who sustain a hip fracture suffer from dementia (109, 110) which also indicates the increased risk of falling among those with cognitive impairment or dementia.

Medical diagnoses
Some medical diagnoses have repeatedly been found to be associated with falls, such as arthritis, stroke, urinary incontinence, depression, circulatory disease, Parkinson’s disease and other neurological diseases (27, 36, 37, 39, 40, 42, 76, 84, 88, 90, 99, 111-116). The risk of sustaining falls was doubled in stroke patients and depressive symptoms in stroke patients predicted falls; the risk increasing with increased depression score (117). Stroke not only increases the risk of falls but also the risk of sustaining fractures on the hemiparetic side due to osteoporosis (118, 119). The risk of sustaining falls increases with chronic disease burden (42, 52, 84). In addition to increasing the risk of falling, depression increases the risk of sustaining fractures (both vertebral and non-vertebral) (113).

Drugs
Falling is one common side effect related to the use of drugs (120-123). Research into drugs as predisposing factors for falls presents a widely varying picture. Numerous studies have analysed a wide range of drugs such as neuroleptics, benzodiazepines, antidepressants,
sedatives, diuretics, beta-blockers, calcium channel blockers, angiotensin-converting enzyme (ACE) inhibitors, digoxin, non-steroidal anti-inflammatory drugs (NSAID), acetylsalicylic acid (ASA), anticonvulsants, narcotic pain killers and laxatives with varying results (47, 90, 123-134). One problem is the methodological variations regarding both registration and grouping of drugs among the studies. In addition smaller studies have not been able to account for subgroups of drugs. Thus, it has been difficult to use meta-analyses to analyse subgroups of drugs. Furthermore, in prospective studies with long follow-ups for falls, often 6-12 months (40, 47, 90, 128), the drugs prescribed were registered at baseline but there were no checks for subsequent changes in drug prescription. Thus, the possibilities of drawing conclusions about the association between the drug and the fall have been limited. In addition few studies on drugs as risk factors for falls have used multivariate analyses which makes it difficult to distinguish the independent associations with falls among different drugs and not least between the drug and the underlying diagnosis for which it is prescribed. To date the strongest link with an increased risk of falling has been shown for agents acting on the central nervous system such as antidepressants (tricyclic antidepressants (TCAs) and serotonin-reuptake inhibitors (SSRIs)), neuroleptics, benzodiazepines and antiepileptics (127, 131, 133) but also class IA antiaryrrhythmics (130).

Polypharmacy (four or more drugs) has been shown in some studies to be associated with falls (40, 83) but not in others (84), and Lawlor et al showed that chronic diseases and multiple pathology are more important predictors of falling than polypharmacy (84, 97).

**Fear of falling**

Those with a fear of falling have an increased risk of falling but falls also predict fear of falling (76, 135).

**Prediction of falls**

It is assumed that the cumulative effect of multiple risk factors contributes more to the tendency to fall than the potential effect of each risk factor alone (136). On the basis of this assumption, a number of fall risk assessment tools, based on scoring systems screening for established risk factors, have been developed (82, 137-142). Most tools are developed for people in hospitals (137, 139-141) and fewer for older people in institutions. The Tinetti fall risk index was developed to predict falls in older people in residential care, but seems too complex to be used conveniently in clinical practice and only part of the index, the Tinetti balance scale, has been validated externally (143). Another extensive assessment that is not practical for ordinary use is the Physiological Profile Assessment (PPA) (144). The Mobility
Interaction Fall (MIF) chart is a flow chart developed for older people in residential care (142) that has been evaluated in a new sample, but the predictive value was then even better when combined with staff judgment or fall history (145). The Downton index has been shown to be a useful tool for predicting falls among older people in residential care (146). Both the MIF chart and the Downton index are quick and easy to perform and therefore usable in clinical practice.

The St Thomas’s risk assessment tool in falling elderly inpatients (STRATIFY) (141) has been validated in new samples with different results (147, 148).

The prevention of falls in the elderly trial (PROFET) is an assessment tool developed as a practical risk-based approach to streamlining referrals when older people present to an accident and emergency department with a fall (149), but has yet not been externally validated.

**PRECIPITATING FACTORS**

Efforts to determine precipitating factors for falls have been made in some studies (15, 20, 39, 46, 82, 124). *Acute disease* has been found to precipitate 5-23% and *medication* 5% of the falls in older people (20, 39, 46). One third of the recurrent fallers fell during an acute illness according to another study among older people living in intermediate care facilities (82). *Gait or balance disturbances* as well as *dizziness and confusion* have been detected as immediate causes of falls especially in frail older people living in institutions (15). Both the effects and adverse effects of drugs can cause falls through many different mechanisms (123).

*External factors and environmental circumstances*, such as wet floors, objects tripped over, poor lighting, bedrails and stairs have been found to contribute to the risk of falls and injurious falls among older people but have mostly been studied in the home environment (15, 20, 39, 58, 78, 150-152). However, some studies do not support the association between environmental hazards and falls (153, 154).

*Cardiovascular symptoms and diseases*, such as vasovagal syncope, carotid sinus hypersensitivity, orthostatic hypotension, postprandial hypotension and baroreflex abnormalities present as un-explained falls (29, 155-158). Orthostatic hypotension has been shown to be an independent risk factor for recurrent falls (99, 159) but orthostatic hypotension is poorly reproducible (160) and correlates poorly with symptoms (161). A significant association between atrioventricular block, sick sinus syndrome, and falls has been shown (162). Furthermore 1/4 of reported cases of syncope have underlying cardiac etiologies.
and about 1/4 of older people with falls or syncope experience postprandial hypotension.

WEATHER AND HEALTH

There is a widespread assumption that weather conditions influence health in some ways and older people reporting that the weather affects joint and body pain are a common occurrence in clinical geriatric practice. However, the findings are rather inconsistent in the literature. Seasonal variations have, however, been shown in musculoskeletal symptoms, rheumatic pain, (165, 166) incidence rate of hip and forearm fractures, (79-81), of sudden death (167) and in exacerbations of Crohn’s disease and ulcerative colitis (168, 169).

Studies on the influence of weather conditions on rheumatic pain for example are contradictory and difficult to compare because of differing meteorological variables and disparities in diagnoses and pain measures. An association between weather factors, e.g. cold and damp, and musculoskeletal symptoms is considered to be plausible in a literature review (165). Several studies support the view that meteorological factors (e.g. low or reduced temperature, high atmospheric pressure, high or increased relative humidity) can affect rheumatic pain (166, 170-172) while others have found weaker or no associations (173, 174).

In addition several studies have described a relationship between the weather and the incidence of acute myocardial infarctions and sudden cardiac deaths (175, 176). Bronchial hyper-reactivity and asthma has been reported to be associated with higher humidity and lower temperature (177, 178).

Outdoor falls increase with extreme cold but also during warmer periods (179), however the association between indoor falls and weather conditions has barely been studied. There are results that show an increase in the number of falls in older people in winter, also increasing with lower temperature (180). Risk factor profiles have been found to differ between indoor and outdoor fallers, indoor falls being associated with frailty and outdoor falls with compromised health status in more active people (181). Most findings regarding seasonal variation of hip and forearm fracture incidence, an indirect measure of falls, show a seasonality (79-81), but there are studies that show no seasonality in hip fracture incidence (182).

Weather and climatic factors are thought to influence some medical conditions. Since older people in residential care facilities are frail and have a lot of predisposing factors for falls
leading to a lowered threshold for sustaining falls, changes in the weather could perhaps be one more factor lowering the fall threshold or they could be the factor that pushes the person over the fall threshold.

**PREVENTION OF FALLS AND FALL-RELATED INJURIES**

Over 60 randomised controlled trials of interventions to prevent falling, mainly in community dwellers, have now been published according to the two latest reviews and meta-analyses done in the field (22, 23). The results are inconsistent and many of the studies are difficult to compare due to a great variation in study design with different target groups, outcome measures, multifactorial or single but different factor interventions.

There is agreement that multifactorial risk assessment and management programmes are effective, but it is not possible to say which are the components that are effective. In single intervention studies individually targeted exercise programs seem to be effective, but the effect of group exercise is uncertain (22, 183, 184). Environmental modifications are probably not effective (23), but there is uncertainty (22). Withdrawal of psychotropic medication seemed effective, but the challenge is that many participants later returned to previous medication patterns (185). Overall, only modest reductions have been achieved and many of the possible interventions are both labour intensive and expensive (186).

Fewer studies have been performed in institutional care, and there are some positive results (31, 187, 188). Though only one of them have reported a reduced incidence of femoral fractures (31).

Some studies with positive results have included cognitively impaired people (31, 189, 190), but to date no controlled prevention studies have proved to be effective when focusing on older people with cognitive impairment and dementia (107, 191, 192).

In recent studies vitamin D and calcium supplements have been shown to reduce not only fractures but also the incidence rates of falls and the number of fallers, both among community dwellers and in older people in long-stay geriatric care, probably due to improvement in musculoskeletal function (193, 194).

Promising safety promotion programs have been implemented in several Swedish communities, but have unfortunately not been evaluated in a randomized manner with the
focus on falls and fall-related injuries in older people (195, 196). In the United Kingdom a successful interdisciplinary and multifactorial fall-prevention program directed to older people presenting to accident and emergency departments with a fall have been implemented and included in legislation (190).

**RATIONALE FOR THIS THESIS**

Falls are a common and an increasing health problem, causing physical, psychological and social problems for the individual older person and increasing costs for society. Yet we can still only explain a minority of falls.

New medical drugs are constantly introduced in medical therapy and very seldom are studies done on any older population before a drug is registered. Knowledge about side-effects, including falls, in older people is therefore incomplete and there is a continuous need for new studies. Furthermore multivariate analyses have to be used to distinguish between different drugs as well as between drugs and diagnoses as independent factors associated with falls. Few studies have distinguished between drugs as predisposing and as precipitating factors.

The development of fall-prevention programs for older people in geriatric care settings are crucial and urgent, in view of the fact that the world’s population is ageing fast and thus increasing numbers of people are at risk of falls. Some intervention studies have been successful, but only in older people whose cognitive functioning is better and mainly in community-living older people. It is important to identify those most at risk of falling in order to maximize the effectiveness of any proposed intervention. Knowledge about falls and the circumstances in which falls occur in older people, not least in geriatric care settings and in older people with cognitive impairment, is incomplete. As the world’s population ages, increasing numbers of people with dementia can be expected and the factors associated with falls in people with cognitive impairment are poorly mapped out. In addition, little is known about the distribution of indoor falls over time and the association between indoor falls and weather.
AIMS OF THIS THESIS

With the prevention of falls in older people as the overall objective, the general aim of this thesis was to identify people at increased risk of sustaining falls by investigating predisposing and precipitating factors for falls among older people living in geriatric care settings.

The specific aims were:

- To identify predisposing and precipitating factors for falls and recurrent falls among frail older people living in residential care facilities (Paper I).
- To identify precipitating factors for falls among older people living in residential care facilities by analyzing the circumstances – related to the individual and to the environment – prevailing at the time of the fall (Paper II).
- To study factors associated with falls in older people in geriatric care settings, focusing on pharmacological treatment (Paper III).
- To examine factors associated with falls among cognitively impaired older people in geriatric care settings (Paper IV).
- To describe the variation of falls over time and analyse whether there are any associations between falls and weather in older people in residential care (Paper V).
METHODS

The term “older people” is, as far as possible, used in this thesis, the only exceptions being in the two papers first published, Paper I and II, and sometimes when referring to older studies. The term “older people” is used mostly to include people aged 65 years or older, which is also the definition used in this thesis.

SUBJECTS AND SETTINGS

Three main samples of older people in geriatric care settings in the county of Västerbotten in northern Sweden, were included in this thesis (Tables 1-3).

Residential care facilities in Sweden accommodate older people who are disabled because of cognitive or physical impairment and thus require supervision, functional support, or nursing care. Residential care facilities include senior citizens’ apartments, old people’s homes and sometimes group dwellings for people with dementia. In senior citizens’ apartments, the residents live in private apartments with 1 or 2 rooms, a kitchen, and a bathroom. In the old people’s homes like in the group dwellings, the residents live in private rooms including a bathroom, and have their meals in a shared dining room. In all facilities, residents have 24-hour access to assistance with activities of daily living, household issues, nursing and medical care. Staffing levels in group dwellings for people with dementia are high compared to those in other facilities. Residents living in nursing homes usually have their own room, but in some facilities they share a room with up to 3 people. Nursing staff are available all the time. In Sweden 8% of people aged 65 years and older live in residential care facilities, dwellings for people with dementia and nursing homes, according to statistical reports from The National Board of Health and Welfare in Sweden (2003).

The first sample (Paper I) comprised 83 residents living in one residential care facility, including senior citizens’ apartments, an old people’s home and a group dwelling for people with dementia, in Umeå, a city in the county of Västerbotten in northern Sweden.

The second sample (Paper II and V) comprised 439 residents living in nine residential care facilities, including senior citizens’ apartments, old people’s homes and group dwellings for people with dementia, in Umeå.
The third sample (Papers III and IV) included 3,669 residents living in all geriatric care settings in the county of Västerbotten; 68 residential care facilities (including senior citizens’ apartments and old people’s homes), 31 nursing homes, 66 group dwellings for people with dementia, 7 rehabilitation/short-stay units, 2 somatic geriatric, and 2 psychogeriatric clinics.

**PAPER I**

Eighty-three residents participated in the study, of whom 23 lived in senior citizens’ apartments, 37 lived in the old people’s home and 8 in a dwelling for people with dementia. Sixty-eight residents lived in the setting at the start of the study and 15 moved in over a period of one year, as the same number of people either died or moved to nursing homes. The mean age ± SD (range) was 79.6 ± 8.6 (54-99) years and 70% were women. Three residents younger than 65 years (54, 56 and 60 years) were included as they were regarded as frail due to physical and cognitive impairments. All residents, or in the case of dementia their relatives, gave their informed consent to participation.

**PAPER II**

Paper II included residents living in five of the nine residential care facilities (including senior citizens’ apartments, old people’s homes and group dwellings for people with dementia). These participants are described as the second sample. These five facilities comprised the intervention group in a fall prevention study, and were the facilities where post-fall assessments were performed (31). One hundred and ninety-nine out of 224 eligible residents were included after their own, or in case of dementia their relatives’, informed consent had been obtained. The mean age ± SD (range) was 82.4 ± 6.8 (65-97) and 70% were women.

**PAPER III-IV**

A total of 4,357 residents living in the geriatric settings were included and 3,804 of them were assessed (87%). When residents younger than 65 years were excluded, 3,669 remained. In 65 cases data about falls were missing leaving 3604 residents who were included in the analyses in Paper III. The mean age ± SD (range) was 83.3 ± 7.0 (65-103) years and 68% were women.

In 3,323 residents aged 65 years and older data about both falls and cognition were collected. Of these residents 2,008 (60%) were cognitively impaired and they became the study population in Paper IV. Of these participants 69% were women and the mean age ± SD (range) was 83.5 ± 6.8 (65-101) years.
**PAPER V**

Residents in all the nine facilities, described as the second sample, were included in this paper (n=439). It was possible to assess 402 of the residents at baseline after their own, or in case of dementia their relatives’, informed consent had been obtained. Seventy-two percent were women and the mean age ± SD was 82.8 ± 6.8.

**ETHICAL APPROVAL**

The studies were approved by the Ethics Committee of the Faculty of Medicine at Umeå University (§ 84/94, § 3/98, registration number 97-395 and §93/00, registration number 00-070).
Table 1. A schematic overview of the studies comprising the thesis

<table>
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</thead>
<tbody>
<tr>
<td><strong>Context of the study</strong></td>
<td>1 Residential care facility*</td>
<td>5 Residential care facilities*</td>
<td>176 Geriatric care settings#</td>
<td>176 Geriatric care settings#</td>
<td>9 Residential care facilities*</td>
</tr>
<tr>
<td><strong>Study design</strong></td>
<td>Prospective cohort study</td>
<td>Prospective cohort study</td>
<td>Cross-sectional study</td>
<td>Cross-sectional study</td>
<td>Prospective cohort study</td>
</tr>
<tr>
<td><strong>Statistical analyses performed</strong></td>
<td>Chi-square test</td>
<td>Chi-square test</td>
<td>Principal component analysis</td>
<td>Principal component analysis</td>
<td>Poisson regression models</td>
</tr>
<tr>
<td></td>
<td>Fisher’s exact test</td>
<td>Fisher’s exact test</td>
<td>Logistic regressions</td>
<td>Logistic regressions</td>
<td>Rates</td>
</tr>
<tr>
<td></td>
<td>Student’s t-test</td>
<td>Student’s t-test</td>
<td>Correlation analyses</td>
<td>Correlation analyses</td>
<td>Autocorrelations</td>
</tr>
<tr>
<td></td>
<td>Factor analysis</td>
<td>Mann-Whitney U test</td>
<td>Logistic regression analyses</td>
<td>Logistic regression analyses</td>
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<td></td>
<td>Logistic regression analyses</td>
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</table>

* Including senior citizens’ apartments, old people’s homes and group dwellings for people with dementia

# Including 68 residential care facilities (including senior citizens’ apartments and old people's homes), 31 nursing homes, 66 group dwellings for people with dementia, 7 rehabilitation/short-stay units, 2 somatic geriatric and 2 psychogeriatric clinics
Table 2. Assessments performed at baseline

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<tbody>
<tr>
<td>MDDAS</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MADRS</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barthel ADL index</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timed Up and Go</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional Reach</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood Tests</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3a. Baseline characteristics of the residents

<table>
<thead>
<tr>
<th>Age (mean ± SD) (range)</th>
<th>Paper I (n=83)</th>
<th>Paper II (n=199)</th>
<th>Paper III (n=3604)</th>
<th>Paper IV (n=2008)</th>
<th>Paper V (n=439)</th>
</tr>
</thead>
<tbody>
<tr>
<td>79.6 ± 8.6 (54 – 99)</td>
<td>82.4 ± 6.8 (65-97)</td>
<td>83.3 ± 7.0 (65-103)</td>
<td>83.5 ± 6.8 (65-101)</td>
<td>82.8 ± 6.8 (65-100)</td>
<td></td>
</tr>
<tr>
<td>Women (%)</td>
<td>69.9</td>
<td>70.4</td>
<td>67.6</td>
<td>69.0</td>
<td>71.6</td>
</tr>
</tbody>
</table>

Clinical characteristics (%)

| Depression | 49.4 | 34.7 | - | - | 31.1 |
| Heart disease | 47.0 | 58.8 | - | - | 55.2 |
| Previous stroke | 38.6 | 33.2 | 27.5 * | 26.3 * | 33.1 |
| Dementia | 47.0 | 35.7 | 55.1# | 100# | 35.6 |
| Impaired vision | 20.5 | 25.1 | 14.2† | 15.6† | 23.9 |
| Osteoarthritis | 22.9 | 29.1 | - | - | 27.6 |
| Previous falls (%) | 44.6 | 41.2 | 43.9 | 49.9 | 39.8 |
| (preceding 12 months) | (preceding 6 months) | (during stay) | (during stay) | (preceding 6 months) |
| Physical restraints‡ | 4.8 | 10.5 | 17.4 | 26.2 | 14.4 |

*States of slight hemiparesis to total hemi- or paraplegia according to MDDAS (197)

# Cognitive impairment according to Gottfries and Gottfries subscale (198)

† Blindness and severely impaired vision according to MDDAS (197)

‡Including bedrails, geriatric chairbelts and chairs with fixed tray table in Papers I, II and V and geriatric chairbelts, chairs with fixed tray table and locked room doors, but not bedrails, in Papers III and IV
### Table 3b. Baseline characteristics of the residents, measures of function

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>MADRS score*</td>
<td>9.8±9.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MMSE*</td>
<td>19.1±8.4</td>
<td>18.7±7.8</td>
<td>-</td>
<td>-</td>
<td>17.8±8.0</td>
</tr>
<tr>
<td>Cognition*#</td>
<td>-</td>
<td>-</td>
<td>17.0±9.1</td>
<td>11.2±7.0</td>
<td></td>
</tr>
<tr>
<td>Barthel ADL Index*</td>
<td>14.4±4.9</td>
<td>13.4±5.5</td>
<td>-</td>
<td>-</td>
<td>12.8±5.7</td>
</tr>
<tr>
<td>Independent walking</td>
<td>83.1†</td>
<td>68.8†</td>
<td>44.9‡</td>
<td>38.9‡</td>
<td>68.4†</td>
</tr>
<tr>
<td>with or without walking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>aid (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise from a chair (%)</td>
<td>-</td>
<td>-</td>
<td>64.3</td>
<td>55.8</td>
<td>-</td>
</tr>
<tr>
<td>Users of a walking aid</td>
<td>37.3</td>
<td>34.7</td>
<td>48.6</td>
<td>40.8</td>
<td>37.6</td>
</tr>
<tr>
<td>(%)</td>
<td></td>
<td></td>
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</tbody>
</table>

* Mean±SD

# Cognitive impairment according to Gottfries and Gottfries subscale (198)

† According to Barthel ADL index (199)

‡ Walks without walking aid according to MDDAS (197)

### Table 3c. Baseline characteristics of the residents, drugs prescribed

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Number of drugs (Mean±SD)</td>
<td>-</td>
<td>6.5±3.5</td>
<td>6.5±3.5</td>
<td>6.5±3.2</td>
<td>6.4±3.3</td>
</tr>
<tr>
<td>Antidepressants (%)</td>
<td>25.3</td>
<td>30.2</td>
<td>39.9</td>
<td>43.2</td>
<td>32.3</td>
</tr>
<tr>
<td>Analgesics (%)</td>
<td>38.5</td>
<td>67.3</td>
<td>53.9</td>
<td>58.0</td>
<td>65.9</td>
</tr>
<tr>
<td>Benzodiazepines (%)</td>
<td>20.5</td>
<td>25.6</td>
<td>31.2</td>
<td>29.5</td>
<td>29.9</td>
</tr>
<tr>
<td>Diuretics (%)</td>
<td>42.2</td>
<td>50.8</td>
<td>43.7</td>
<td>37.3</td>
<td>51.7</td>
</tr>
<tr>
<td>Laxatives (%)</td>
<td>12.0</td>
<td>42.2</td>
<td>48.1</td>
<td>56.6</td>
<td>48.0</td>
</tr>
<tr>
<td>Neuroleptics (%)</td>
<td>21.7</td>
<td>24.1</td>
<td>27.3</td>
<td>32.8</td>
<td>27.6</td>
</tr>
</tbody>
</table>
PROCEDURES

PAPERS I, II AND V

Baseline assessments were performed and social and medical data were collected directly from the participants, their medical records, caregivers and relatives. The data collection for Paper I was carried out in 1994-1995, and for Papers II and V in 1998-1999. In addition to sex, age and place of abode a number of characteristics, assumed or regarded as potential risk factors for falls, were collected and assessed for at baseline:

*History of falls* in Paper I was measured as falls in the preceding year and in Papers II and V as falls the preceding six months.

*Diagnosis and medication* were registered by each resident’s physician on a questionnaire. All drugs taken within 24 hours before a fall were also registered. A registered nurse reported whether there had been episodes of delirium the previous month.

*Vision* was judged as impaired if the resident, with or without glasses, could not read a word written in 5 mm capital letters at reading distance.

*Hearing* was rated as impaired if the resident, with or without a hearing aid, could not hear normal speech from a distance of 1 meter.

*Cognitive function* was assessed using the Mini-Mental State Examination (MMSE) (200). The instrument includes six sections; orientation, registration, attention and calculation, recall, language and copying. The maximum score is 30 and a score of less than 24 has been considered to indicate cognitive impairment (200). The MMSE was performed by a physician in Paper I and by a physiotherapist in Papers II and V. Dementia was diagnosed when the DSM-III-R criteria (201) in Paper I and DSM-IV-criteria (202) in Papers II and V were fulfilled.

*Depression* and depressive symptoms were assessed using the Montgomery-Åsberg Depression Rating Scale (MADRS) (203) in Paper I. The scale includes 10 items each of which is scored on a 7-grade scale, giving a maximum score of 30 (including half-numbers) or 60. The version with the maximum score of 60 was used in this study. Higher scores indicate more severe depression. The items are apparent sadness, reported sadness, inner tension, reduced sleep, reduced appetite, concentration difficulties, lassitude, inability to feel, pessimistic thoughts and suicidal thoughts. The scale has good validity and reliability (203,
204). The diagnosis of depression was defined according to the criteria suggested by Snaith (204), score 7/60 in MADRS (Paper I). Participants treated with antidepressants were also regarded as having a depression diagnosis. In Paper I, 41 residents were assessed as having a depression while only 21 were being treated with antidepressants and nine of the 21 residents receiving such treatment were no longer depressed. In Papers II and V the diagnosis of depression was registered by the patient’s regular physician.

Level of independence in Activities of Daily Living (ADL) was assessed using the Barthel ADL index (199) in Papers I, II and V. The index includes 10 items; bowel and bladder continence, grooming, toilet use, feeding, transfer, mobility, dressing, using the stairs and bathing. The maximum score is 20, which implies independence in self-care and indoor ambulation. The index is considered reliable in test-retest between observers and in different settings (199, 205). In Paper I, the registered nurse, employed part-time on the project, performed the assessment. In Papers II and V the score was based on an interview with the nurse’s aid and the licensed practical nurses most familiar with the residents’ abilities.

Basic mobility was quantified by the Timed Up & Go test (TUG) (206) in Papers I and II. TUG measures the time it takes to rise from a chair, walk 3 meters, turn, walk back and sit down again. The test was carried out by a physiotherapist who gave verbal instructions and showed how the test should be performed. The residents were able to do the test once or twice before being timed with a digital stop-watch. The reliability and validity of TUG is high in a sample of old people living in the community (206) and the inter-observer reliability was high in the sample studied in Paper I (207).

Dynamic balance was measured by Functional Reach (FR) (208) and was performed by a physiotherapist. The resident raised the arm to 90° flexion in the shoulder and reached as far as possible in a plane parallel with a yardstick mounted on the wall, without taking a step. FR has high test-retest reliability (208).

Visual perception was assessed using the Line Bisection test by a physician (209).

Walking ability was assessed according to the Barthel ADL Index (199). Two items in the instrument measure walking ability; indoor mobility and ability to go up and down in stairs.

Orthostatism was defined as a drop of more than 10 mm Hg in systolic blood pressure on rising to an upright position after a 5-min rest.
Blood tests such as S-haemoglobin, S-potassium, S-sodium, S-creatinin, S-albumin, S-leukocytes and sedimentation rate (SR) were taken in Paper I.

Height and weight were measured and Body Mass Index (BMI; kg/m$^2$) were calculated.

Weather parameters were measured in Paper V. Mean values for temperature, atmospheric humidity and air pressure based on readings every three hours, daily readings of the mean precipitation and hourly readings of sun minutes were obtained from the Swedish Meteorological and Hydrological Institute (SMHI). Readings of temperature, atmospheric humidity and air pressure were made at Umeå Airport (Northern Sweden) and values for precipitation and sun minutes were obtained from Röbäcksdalen which covers Umeå. The data were completed, for 14 days in March and 12 days in June, with figures for mean temperature, atmospheric humidity and air pressure obtained from Holmögadd. All geriatric care facilities were sited within 10 km of Umeå Airport and Röbäcksdalen and 35 km from Holmögadd and all were located below 65 meters above sea level.

PAPERS III AND IV

The residents were assessed by means of the Multi-Dimensional Dementia Assessment Scale (MDDAS) (197). The MDDAS scale was sent to the various settings and returned. The member of staff who knew the resident best was asked to fill in the assessment scale. The staff received written instructions on how to complete the assessment form and were informed that the members of the research team could answer questions or provide additional guidance by phone. The professional backgrounds of the staff who completed the assessment form were varied but most were nurses. The staff were informed that their assessment should be based on observations of the resident’s habitual state during the preceding week. The scale measures, for example, mobility, paresis, vision, hearing, functions of ADL, and behavioural and psychiatric symptoms. It also includes a registration of current drug prescription, which was collected from the medical records and filled in by a registered nurse. Vision was judged as blindness, severely impaired vision, moderately impaired vision or good vision. Blindness and severely impaired vision were grouped together in the analysis and labelled impaired vision. The label paresis covered states of slight hemiparesis to total hemi- or paraplegia. An ADL score (4-24 points) was calculated based on the resident’s ability to cope with dressing, hygiene, eating, bowel and bladder control. A higher score indicates a greater ADL independence.
To measure the prevalence of cognitive impairment a sub-scale of the MDDAS developed by Gottfries and Gottfries was used (198). This scale consists of 27 items measuring the resident’s ability to orient him/herself. Residents scoring lower than 24 points are considered to be cognitively impaired. This part of the instrument has been validated against the Mini Mental State Examination (MMSE) (200) with a sensitivity of 90 % and a specificity of 91 % to differentiate between residents with dementia and those without (197).

**FOLLOW-UP FOR FALLS AND FALL-RELATED INJURIES**

In Papers I, II and V the follow-up period for falls was 12 months, or until the resident died or moved. A fall was defined as an event in which the resident unintentionally came to rest on the floor, regardless of whether an injury was sustained, including falls resulting from an acute illness or epileptic seizure and incidents that resulted in a resident’s falling and being found on the floor by staff or other residents, but not incidents when someone came to rest or tumbled against a piece of furniture, a wall or other structure (31).

The staff filled in a structured fall report immediately after a fall. The reports were collected by the research team at least every second week. In addition, all documentation was analysed to detect unreported falls. In Papers I and II careful post-fall assessments were carried out. Evaluations of the most probable causes of the fall as well as registration of all injuries were made. The report form in Paper II was further developed in the light of experiences from Paper I.

In Paper I the registered nurse, who was partly employed on the project but was also part of the permanent staff at the facility, and the responsible physician followed up each fall and evaluated its most probable cause.

In Paper II a team comprising a physician, a nurse, a physiotherapist and sometimes other staff members met weekly for post-fall conferences aimed at both evaluating and addressing the most probable cause of the fall and to discuss and decide appropriate preventive measures when possible. After the data collection the research study group (one physiotherapist and two physicians) evaluated all documentation regarding each fall and came to a consensus about the most probable precipitating factor for each fall. Consensus was possible in most cases, but in those cases where there were disagreements the majority decision was adopted or the decision was made that there were two or more precipitants involved in the actual fall.
Injuries were ranked according to the AIS, presenting MAIS, in Papers II and V. In Paper I injuries were classified as minor, moderate and severe, corresponding to MAIS 1, 2 and 3 respectively. In Paper II tenderness, soreness and pain without any reported visible injury were classified as MAIS 0.5 and included in injuries presented, but in Paper V only injuries rated as 1 or more were included. In Table 4 all injuries, also including MAIS 0.5 in Paper II, are presented for all the studies.

In Papers III-IV falls and resulting injuries in the preceding week were registered on the MDDAS assessment form. The question about falls was formulated as follows: “Has the resident, during the preceding week, sustained any fall accident (unintentionally come to rest on the floor or other lower level from a walking, standing, sitting or lying position)?”. The injuries were classified as minor injuries, including bruises, minor cuts or abrasions and as serious injuries, including fractures, cuts needing stitches, head injuries and injuries to internal organs.

**STATISTICAL ANALYSES**

The incidence rates of falls and injuries were calculated as the number of falls or injuries divided by the total number of person days (Papers I and II) or the number of falls or injuries per calendar day divided by the number of people at risk each day (Paper V). In Papers III and IV the number of fallers per Person Year (PY) were calculated, which is the number of fallers during one week divided with the number of person days. The observation time was counted from the start to the end of the study or until the resident moved or died. Days spent outside the facility, if more than three, were subtracted.

Comparisons between fallers/non-fallers (or non-fallers and single fallers/recurrent fallers) and categorical background factors were made using the chi-square test or Fisher’s exact test (Papers I and II). Student’s t-test was used for continuous background factors (Papers I and II) and the Mann-Whitney U test for ordinal or skewed data when appropriate (Paper II).

Logistic regression analyses were used to analyze univariate (Papers III and IV) and multivariate relationships (Papers I, II, III, IV). The logistic regression analysis in Paper IV was controlled for the potential effects of clustering, where cluster was settings. Variables significantly associated with falls in the univariate analyses were first entered into a correlation analysis to check for multicolinearity and then into multivariate logistic regression.
analyses to identify factors associated with falls (Papers I, II, III and IV) or recurrent falls (Paper I). The variables that were judged to have the best association with the outcome variable were included in the final multivariate logistic regression model.

For subclassification of the psychiatric symptoms in Paper IV a factor analysis using the Varimax rotation method was applied. Items with loadings >0.3 were considered in the construction of factors. The number of factors was selected based on the eigenvalue criterium (eigenvalue larger than one).

In Paper V the association between fall rate and weather characteristics was analysed using a Poisson regression model with overdispersion. Rates were also calculated for different time intervals, hours within days, days of the week, months and quarter of the year. Autocorrelations were calculated in order to evaluate the dependency between successive days.

$P$ values <0.05 were regarded as statistically significant. All calculations were made using the statistical package SPSS® (SPSS Inc., Chicago, Illinois) version 6.1 (Paper I), 10.0 (Paper II, III and IV) or 11.0 (Paper V) and Stata Software (Stata Corporation, College station, Texas) version 8.0 in Paper V.
RESULTS

PREDISPOSING AND PRECIPITATING FACTORS FOR FALLS AMONG OLDER PEOPLE IN RESIDENTIAL CARE (PAPER I)

When analysing predisposing factors in logistic regression models, treatment with antidepressants (SSRIs), impaired vision and an inability to use stairs without assistance were the factors found to be independently associated with being a faller and treatment with antidepressants (SSRIs), previous falls, older age and an inability to bath without assistance with being a recurrent faller (Tables 4 and 5).

Sixty-three percent of the residents fell at least once during the one-year follow-up. The incidence rate was 2.3 falls / PY. Sixty-five percent of the fallers sustained more than one fall and were defined as recurrent fallers. Fifty-four percent of the fallers, 28% of those who fell once and 68% of the recurrent fallers, suffered injuries. Fractures were sustained in 33% of the fallers and 58% of the falls resulting in fractures were judged to be precipitated by acute illness, the side-effects of drugs or by vertigo (Table 6).

Twenty-seven percent of all falls were judged to be precipitated by an acute illness or disease, 9% of the falls by a drug and 5% by vertigo. Infections were the most common acute diseases accounting for 16%, while acute stroke precipitated 4% and heart disease and psychiatric symptoms were judged to precipitate 2% of the falls respectively. The most frequent drugs involved in precipitating falls were antidepressants (3%), diuretics and neuroleptics (2% respectively) (Table 7).

In this study 41 residents were assessed as depressed while only 21 were actually receiving treatment with antidepressants. Nine of the 21 residents receiving treatment with antidepressants were no longer depressed according to Snaith’s criteria (204). It was possible to analyze statistically their association with falls independently. According to our multivariate analysis, treatment with antidepressants seems to be more important than depression as a fall risk factor.
WHY THE ELDERLY FALL IN RESIDENTIAL CARE FACILITIES, AND SUGGESTED REMEDIES (PAPER II)

The most probable precipitating factors for the falls could be judged in 69% of the incidents. Acute disease or symptoms of disease, including exacerbations of chronic diseases and syncope, were judged to be precipitating factors in 39% of all falls. Eight percent were precipitated by infections, most often symptomatic urinary tract infections, 11% by acute stroke and 10% by delirium. Seven residents sustained 19 falls under the influence of alcohol (Table 7).

Drugs were judged to be precipitating factors in 8% of the falls. Benzodiazepines and/or neuroleptics were involved in 86% of these falls.

External factors precipitated 8% of the falls, most often in form of obstacles or defective materials. Thirty-four residents were using hip protectors and hip protectors were judged to precipitate 3 falls as they got stuck at the knees when the wearer was dressing.

Other conditions, due to both the individual and the environment, were judged to precipitate 17% of the falls. Errors of judgement/misinterpretation eg, overestimation of one’s own ability or forgetfulness on the part of the resident, precipitated 34 falls. Misuse of a walker precipitated 15 and miscalculation, probably because of perceptual disturbances, precipitated 14 falls. Mistakes made by the staff, such as leaving a resident alone on the toilet, forgetting to put on parts of a wheelchair or turning off the light at night – all in contravention of agreements – lay behind 12 falls.

A multiple regression analysis revealed that previous falls (the preceding 6 months) and treatment with antidepressants were the factors independently associated with falls (Tables 4 and 5).

Fifty-seven percent of the residents fell at least once during the one year follow-up. Sixty-five percent of the fallers sustained at least one injury and 32% of the falls resulted in an injury, no injury ranked higher than 3, according to the AIS (Table 6). If only injuries AIS 1 were included, 20% of the falls resulted in injuries and 50% of the fallers suffered at least one injury.
DRUGS AND FALLS IN OLDER PEOPLE IN GERIATRIC CARE SETTINGS (PAPER III)

The number of drugs prescribed was significantly higher among fallers. In univariate analyses use of antidepressants, neuroleptics and benzodiazepines was significantly associated with falls. So also was the use of analgesics, levodopa, cyanocobalamin and levothyroxine. Analysis of subgroups of antidepressants showed that SSRIs were significantly associated with falls, which SNRIs and tricyclic antidepressants (TCAs) were not. In the analyses of subgroups of neuroleptics, propiomazine and olanzapine were shown to be bordering on a significant association with falls but haloperidol or risperidone were not. No subgroup of benzodiazepines was significantly associated with falls. Among the analgesics NSAID and paracetamol, but not opioids, were significantly associated with falls. No other drugs or subgroups of drugs, such as cholinesterase inhibitors, digoxin, diuretics, antihypertensives, ACE inhibitors, nitrates, laxatives, antiepileptics, antihistamines or antibiotics showed any significant associations with falls in this study. No group of drugs increased the risk of injuries when falling (Table 4).

Analysis of the data in multivariate logistic regression models showed that a history of falls, rising from a chair, needing a helper when walking, pain, cognitive impairment, use of neuroleptics and use of antidepressants were all associated with sustaining falls (Tables 4 and 5).

Eight point four percent had sustained at least one fall during the preceding week, which corresponds to a fall incidence of 4.3 falls / PY, if the data is extrapolated to one fall per faller during one week. When dividing the residents into cognitively impaired and unimpaired, according to the Gottfries and Gottfries subscale with a cut off at 24/27, 9% versus 7% of the residents had sustained at least one fall (p= 0.007). Fifteen percent of the fallers had sustained serious injuries and 46% of the fallers had sustained minor injuries, such as bruises or minor cuts or abrasions. Only 38% had no registered injury from their fall (Table 6).
Fallers functioned better in cognition and ADL than non-fallers, but the associations were not linear. People with low cognitive function (score 0-7) and low ADL functions (score 4-8) had the lowest risk of falling, while those with intermediate values in cognitive function (score 8-15) and intermediate and high ADL functions (score 9-16 and 17-24 respectively) were significantly associated with being a faller. In univariate analyses falls were significantly associated with being able to rise from a chair, needing a helper or an aid when walking and having had previous falls. Behavioral symptoms grouped as escape behavior, wandering behavior, restless behavior and verbally disruptive/attention-seeking behavior, were significantly associated with falls, as was the total behavioral symptom score. Hyperactive, depressive and paranoid symptoms as well as the total score for psychiatric symptoms were significantly associated with falls. The fallers were prescribed more pharmaceutical drugs. Use of selective serotonin re-uptake inhibitors (SSRIs), but not serotonin and noradrenaline re-uptake inhibitors (SNRIs) or antidepressants as a group. Not neuroleptics as a group nor any of the subgroups of neuroleptics were significantly associated with being a faller, but cyanocobalamin was. Cholinesterase inhibitors did not reveal any association with falls (Table 4).

In a logistic regression analysis the factors most strongly associated with falls were being able to rise from a chair, previous falls, needing a helper when walking and hyperactive symptoms (Tables 4 and 5).

In this group of cognitively impaired residents 9% had fallen at least once during the preceding week, corresponding to a fall incidence of 4.9 falls / person year (PY), if the data is extrapolated to one fall per faller during one week. Twenty-seven (14%) of the fallers had sustained serious injuries, such as fractures, cuts needing stitches, head injuries and injuries to internal organs and 93 (49%) fallers had sustained minor injuries. Only 36% sustained no registered injury from their fall (Table 6).
WEATHER AND FALLS IN OLDER PEOPLE IN RESIDENTIAL CARE (PAPER V)

The fall rates varied significantly during the day, between 0.17 and 0.61 / hour / 1000 persons at risk; lowest in the morning (3-5 am) and highest in the evening (6-8 pm). There were also significant diurnal differences between the quarters of the year. In addition there were significantly higher fall rates in April and May as well as in November, December and January compared to the baseline month (February 1998), but there were no differences between days of the week. In an autocorrelation analysis a weak autocorrelation (0.10-0.15), just about significant, was found between days, but not between consecutive days. The rate of injurious falls did not differ during the day or among weekdays but there was a significant increase in April and a tendency towards a difference in November and December, compared to February.

There were no associations between fall rates and any of the weather parameters studied, neither according to mean values for temperature, atmospheric humidity and air pressure per day nor to changes in these variables between days or within days. Neither were there any associations between fall rates and precipitation or sun minutes.

Sixty three percent of the residents sustained 1 354 falls, of which 1 329 (98%) were indoor falls, during the twelve-month follow-up. This corresponds to 3.5 falls / person year (PY). There were 303 (22%) injurious falls, no injury was rated more than 3 according to the AIS. Four hundred and fifty of the falls (33%) and 112 (37%) of the injurious falls occurred during the night (9pm-6am) (Table 6).
<table>
<thead>
<tr>
<th>Table 4. Predisposing factors for falls</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Sex</td>
</tr>
<tr>
<td>Previous falls</td>
</tr>
<tr>
<td>Impaired gait and balance</td>
</tr>
<tr>
<td>Impaired vision</td>
</tr>
<tr>
<td>Impaired cognition#</td>
</tr>
<tr>
<td>Behavioural symptoms</td>
</tr>
<tr>
<td>Psychiatric symptoms</td>
</tr>
<tr>
<td>Depression</td>
</tr>
<tr>
<td>Drugs</td>
</tr>
<tr>
<td>Analogesics</td>
</tr>
<tr>
<td>Antidepressants</td>
</tr>
<tr>
<td>Benzodiazepines</td>
</tr>
<tr>
<td>Cyanocobalamin</td>
</tr>
<tr>
<td>Laxatives</td>
</tr>
<tr>
<td>Levodopa</td>
</tr>
<tr>
<td>Levothyroxine</td>
</tr>
<tr>
<td>Neuroleptics</td>
</tr>
<tr>
<td>Polypharmacy</td>
</tr>
</tbody>
</table>

x = Univariate analyses, X = Multivariate analyses

# MMSE (200) / Gottfries and Gottfries (198)
<table>
<thead>
<tr>
<th>Predisposing Factors</th>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
<th>Paper IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (n=83)</td>
<td>Recurrent fallers (n=34)</td>
<td>(n=199)</td>
<td>(n=3604)</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>•Antidepressants</td>
<td>•Previous falls</td>
<td>•Antidepressants</td>
<td>•Previous falls</td>
</tr>
<tr>
<td>Impaired vision</td>
<td>•Previous falls</td>
<td>•Antidepressants</td>
<td>•Rise from a chair</td>
<td>•Previous falls</td>
</tr>
<tr>
<td>Inability to use stairs without assistance</td>
<td>•Older age</td>
<td>•Inability to bath without assistance</td>
<td>•Needing a helper when walking</td>
<td>•Pain</td>
</tr>
<tr>
<td></td>
<td>•Antidepressants</td>
<td>•Previous falls</td>
<td>•Rise from a chair</td>
<td>•Previous falls</td>
</tr>
<tr>
<td></td>
<td>•Needing a helper when walking</td>
<td>•Pain</td>
<td>•Cognitive impairment</td>
<td>•Neuroleptics</td>
</tr>
</tbody>
</table>
### Table 6. Falls, fallers and fall-related injuries

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Incidence rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of falls</td>
<td>163</td>
<td>145</td>
<td>482</td>
<td>-</td>
<td>-</td>
<td>1354</td>
</tr>
<tr>
<td>Fallers sustaining injuries (%)</td>
<td>53.8</td>
<td>67.6</td>
<td>65.5</td>
<td>61.5</td>
<td>63.5</td>
<td>-</td>
</tr>
<tr>
<td>Falls resulting in fractures (%)</td>
<td>11.6</td>
<td>32.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fallers sustaining fractures (%)</td>
<td>32.7</td>
<td>44.1</td>
<td>3.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Proportion of fallers (%)</strong></td>
<td>62.6 in one year</td>
<td>-</td>
<td>56.8 in one year</td>
<td>8.4 in one week</td>
<td>9.4 in one week</td>
<td>63 in one year</td>
</tr>
<tr>
<td><strong>Fallers sustaining fractures (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fallers sustaining fractures (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Intervention study

# Not cognitively impaired and cognitively impaired, according to the Gottfries and Gottfries subscale (198), respectively

‡ Based on the approximation of one faller per week during one year
Table 7. Precipitating factors for falls

<table>
<thead>
<tr>
<th></th>
<th>Paper I n=163 falls (%)</th>
<th>Paper II n=482 falls (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute diseases and symptoms</td>
<td>31.9*</td>
<td>38.6</td>
</tr>
<tr>
<td>Infections</td>
<td>16.0</td>
<td>7.9</td>
</tr>
<tr>
<td>Acute stroke</td>
<td>4.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Delirium</td>
<td>-</td>
<td>10.0</td>
</tr>
<tr>
<td>Under the influence of alcohol</td>
<td>-</td>
<td>3.9</td>
</tr>
<tr>
<td>Vertigo/Dizziness</td>
<td>4.9</td>
<td>3.3</td>
</tr>
<tr>
<td>Heart disease</td>
<td>1.8</td>
<td>0</td>
</tr>
<tr>
<td>Psychiatric symptoms</td>
<td>1.8</td>
<td>0</td>
</tr>
<tr>
<td>Drug side effects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bensodiazepines</td>
<td>0.6</td>
<td>4.4</td>
</tr>
<tr>
<td>Neuroleptics</td>
<td>1.8</td>
<td>3.3</td>
</tr>
<tr>
<td>Analgesics</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>3.1</td>
<td>0</td>
</tr>
<tr>
<td>Diuretics</td>
<td>1.8</td>
<td>0</td>
</tr>
<tr>
<td>Sedatives</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>External conditions</td>
<td>-</td>
<td>7.9</td>
</tr>
<tr>
<td>Obstacle</td>
<td>-</td>
<td>2.5</td>
</tr>
<tr>
<td>Material defect</td>
<td>-</td>
<td>1.6</td>
</tr>
<tr>
<td>Clothes</td>
<td>-</td>
<td>1.2</td>
</tr>
<tr>
<td>Other conditions</td>
<td>-</td>
<td>17.2</td>
</tr>
<tr>
<td>Error of judgement / misinterpretation</td>
<td>-</td>
<td>7.0</td>
</tr>
<tr>
<td>Misuse of walking frame</td>
<td>-</td>
<td>3.1</td>
</tr>
<tr>
<td>Miscalculation</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td>Mistakes by the staff</td>
<td>2.5</td>
<td></td>
</tr>
</tbody>
</table>

* Including vertigo/dizziness, but not delirium
DISCUSSION

This thesis revealed a high incidence of falls and fall-related injuries in older people living in various kinds of geriatric care settings. It was found that the fall rates varied significantly during the day; lowest in the morning (3-5 am) and highest in the evening (6-8 pm). There was also a significant seasonal variation. A history of falls, functional ability, cognition, treatments with antidepressants, mainly SSRIs and neuroleptics and hyperactivity in people with cognitive impairment, were the most important predisposing factors found. Precipitating factors could be determined in two thirds of the falls the most common being acute diseases and symptoms of disease. Weather conditions were not found to be associated with falls. A large proportion of falls resulted in serious injuries and fewer than half the fallers had no registered injury from falls.

INCIDENCE OF FALLS

An increasing fall incidence among older people in geriatric care settings can be seen against the lower incidence in 1994 (2.3/PY in Paper I), compared to that in the later studies in the same types of settings (3.5/PY in Paper V). Another study shows that the fall-event rates increased each year over three years in the population studied in Paper I (53). In addition, there is some evidence to suggest that age-adjusted fall rates (measured as fall-induced injuries) may be increasing with time (71, 72). It is well known, and has also been shown, that people in geriatric care facilities are becoming older and frailer and a larger proportion have dementia (197, 210). Other recent studies have shown the annual incidence of falls in healthy, active community-living women in the over 70 age group to be 49% (55) and 52% in community-living older people (78). This might also indicate an increasing incidence of falls compared to earlier similar studies among community-living older people (38, 39). When comparing the proportion of fallers in Papers III and IV it seems that the incidence is even higher in the cognitively impaired, which is in accordance with previous studies in similar populations (54) (53). The incidence of falls in Paper II seems to be lower than in Paper V, which probably is a result of the successful intervention that was carried out (31).
DIURNAL AND SEASONAL VARIATION

The fall rates were high round the clock, with the only “low frequency time period” occurring between 3-5 a.m. and the highest rates between 6-8 p.m. The high incidence rates in the evenings and at night show patterns similar to those found in other studies in institutions (43, 53). It has been shown that 44% of older people in geriatric care suffered delirium and 37% of the delirious patients were delirious in the afternoon, evening or at night (211). This evening delirium with its exacerbation of behavioural symptoms is often referred to as “sundowning” in studies of people with dementia (212). Both the number and proportion of people with cognitive impairment are constantly increasing, not least in residential care settings (210). Another reflection is that there are fewer staff on duty in the evenings and especially at nights in residential care facilities, markedly reducing the availability of assistance and supervision, in itself a probable contributory factor to the high fall incidence during these time periods. The distribution of falls by time of day has been shown to be significantly negatively associated with the level of staffing – when staffing was highest, fewer falls occurred (213, 214), but the opposite has been reported in partly different populations (20, 54, 214). The variation of fall rates between months has previously been studied (53) but the seasonal variations seen were not consistent over a three-year follow-up in that study. The monthly variation seen in this study might be a random finding. The seasonality perhaps reflects an association with light – older people seeing badly in the dark and better in the light – enhancing the risk of falling in the darker months. On the other hand, perhaps activity increases during the spring when the light returns in these geographic areas and thus the risk of falling also increases.

INCIDENCE OF FALL-RELATED INJURIES

Of the fallers 54 – 65% sustained at least one injury (Papers I-IV). Injuries are shown to be common, but most common in recurrent fallers, 28% and 68% respectively (Paper I). Twelve percent of the falls resulted in fractures and 33% of the fallers sustained fractures in Paper I. This is a high figure which could be interpreted as a result of a very careful post-fall assessment by the physician, strengthened by the fact that some fractures were detected only after repeated X-ray examinations. Furthermore, the high incidence of falls militates against an insufficient reporting of falls, despite the high proportion of fractures. Fifty-eight percent of the falls resulting in fractures were judged to be precipitated by acute...
illness, side-effects of drugs or by vertigo (Paper I) compared to 41% of the falls being precipitated by acute diseases or drug side effects. One interpretation could be that falls precipitated by acute diseases and side effects of drugs result in more injurious falls, because acute diseases and drug side effects reduce the person’s ability to break the fall. Another explanation could be that old people suffering acute diseases are more frail, which might contribute to the risk of suffering injuries from the falls. Injurious falls seem to be more common among people in institutional care compared to community-living fallers (15, 44, 48), probably because of a higher prevalence of frailty including a high prevalence of osteoporosis and malnutrition (215, 216). The more frail the person, the higher the risk that a small change in the health status will precipitate a fall, but also that the fall will result in injury. The results from Papers I and II support this interpretation.

In Papers III and IV the proportions of fallers sustaining serious and minor injuries were 15 /14% and 46 /49% respectively. These are higher figures than have previously been reported, but could be a mark of a frailer population, who are also becoming increasingly frail (197, 210), but the reliability of the figures is not the same as in Papers I, II and V, since the registration of falls and injuries was not prospectively performed.

In Paper V the incidence of injurious falls (22%) was lower than in Papers I and II. This might be the result of the fact that only half of the sample in Paper V were subject to a careful post-fall assessment resulting in an under diagnosis of injuries in the other half of the population. The incidence of injurious falls in Paper V is however comparable to that in previous studies with a similar follow-up for injuries as in the control group in Paper V (48). The interpretation is that if a careful assessment is not performed after a fall, especially in people with dementia, the proportion of injuries will be underestimated.

**PREDISPOSING FACTORS**

All five studies have included only older people in geriatric care settings. This means that the participants as a group have a higher fall risk than home-dwelling older people, for example. Studying only people in institutions might influence the possibility of detecting some fall risk factors that may be found when comparing more vital older people living at home with frailer older people in institutional care.
In Paper I the fallers and recurrent fallers were older than the non-fallers but there were no *age-differences* in the other studies (Papers II, III and IV). The age is high in all the samples which might have limited the possibility of detecting any age differences between fallers and non-fallers. In addition there was no association between *sex* and being a faller in these studies, which can perhaps be interpreted as an expression of the finding that the sex differences seem to level out with increasing age (38, 42, 43). The majority of medical research is in general performed on males which is problematic when the conclusions and consequences (for example drug treatment) are then transferred as valid for the female population too. It would have been interesting to study females and males separately in these studies too, but unfortunately the number of male fallers was too small to allow more than limited sub-analyses.

*Previous falls* was associated with being a faller and a recurrent faller in all four studies in univariate analyses (Papers I-IV) and remained in the multivariate analyses as independently associated with falling in Papers II and IV and with recurrent falling (Paper I). A history of falls seems to be one of the most important factors associated with falling and there is also extensive evidence for this also in previous studies (92, 96, 97, 108). Having had a fall previously is not, of course, a risk factor for falls in the proper sense of the word, but it is a marker of a person with an increased risk of sustaining recurrent falls. This association indicates the useful and easy possibility of making a fall risk evaluation in order to prevent further falls, secondary prevention, and thus fractures, which has been suggested and also found to be valuable in previous studies (145, 217). The goal is obviously to be able to perform primary prevention, as well.

All studies (Papers I-IV) confirm the role of physical impairment leading to *gait and balance problems* and various difficulties in managing the *activities of daily living* as important predisposing factors for sustaining falls. The results from Paper IV showing that the association between falls and a decline in ADL functioning was not linear, that it was the medium-level functioning group that was at highest risk of sustaining falls, is interesting. Impaired ADL function and cognition showed covariation, but if you are not able to rise from a chair, the level of cognition is less important from a fall risk perspective. This is also a primary item checked for in the MIF flow chart. If one is immobile, the risk of falling is low (142) regardless of other risk factors for falling. This finding agrees well with most experiences from clinical work. Other studies have reported an increasing risk of falls with
increasing dependency (83, 96, 108, 218), but have not analysed different levels of ADL dependency in relation to fall risk.

*Cognitive impairment* was associated with falls, almost without exception, in univariate analyses (Papers I-IV) and in accordance with previous studies (39, 106, 107). In Paper IV the analyses showed that the association with falling was not linear, the people with intermediate values for cognitive functioning comprised the group with the highest risk of falling. This is probably a reflection of the functional decline that follows the decline in cognition (perception disturbances, motor skill disturbances, apraxia, agnosia, executive dysfunction and judgement). But, as previously discussed, when you are immobile the risk of sustaining falls is low regardless of the cognition level.

The different behavioural symptoms connected with cognitive impairment and dementia shown to be associated with falls (Paper IV), are mainly behaviours associated with an increased physical activity and mobility. This, in combination with a physical decline for example gait problems, and memory problems, makes the increased risk of falling obvious. Furthermore, the use of psychotropic drugs in particular is more common among demented people (219) and these drugs are considered to constitute risk factors for falls.

*Medical diagnoses* as predisposing factors for falls were only studied in Papers I and II. Depression, constipation, delirium in preceding month and orthostatism were found to be associated with being a faller in univariate analyses. However, no medical diagnoses remained in multivariate analyses. Depression, for example, has been reported in some previous studies to be associated with falls (39, 88, 90, 113), but the conclusion from Paper I was that it was the antidepressants and not the depression itself that were associated with falling, which perhaps was also the case in some older studies when multivariate analyses were not performed.

The role of *drug treatments* as predisposing factors for falls is possibly over-estimated in general opinion, perhaps due to older studies analysing the association between falls and drugs only in univariate analyses. However, the importance of antidepressants, especially SSRIs, is consistent throughout these studies (Papers I-IV) and in line with several previous studies (127, 129, 131-133). In Papers III and IV treatment with SNRIs or TCAs was not associated with falling, pointing to the possibility that there may be differences between groups of antidepressants regarding fall risk, but there was no testing of the differences between SSRIs and SNRIs regarding association with falls. That TCAs were not associated with falling is not in accordance with previous studies (124, 126, 131) but there could have
been a confounder by indication – the people who tolerated these older antidepressants still were prescribed them, while those who suffered from drug side effects were prescribed newer agents, such as SSRIs. Although provable only by randomised studies of withdrawal or non-prescription, it no longer seems reasonable to doubt the relation between antidepressants, not least SSRIs, and falls.

Benzodiazepines and neuroleptics were on the border of being significantly associated with being a faller in univariate analyses in Paper III, but there were no associations in Papers I, II and IV, in opposition to what has been reported previously (123, 131).

The explanation for the absence of associations between falling and diuretics, antihypertensive agents, cardiac medications and laxatives previously found to be associated with falling perhaps is that they have been markers of increased frailty in older people accompanied by multiple risk factors. Maybe the association of drugs with falls lies in their influence as precipitating factors, due to side-effects when newly prescribed or elevated doses – precipitating 8 and 9% of the falls (in Papers I and II respectively), especially in this group of frail older people. Drugs might precipitate falls by inducing hypotension, syncope, epileptic seizure, delirium, sedation, impaired postural stability, iatrogenic Parkinson’s disease, hypoglycaemia and neuropathy (123). Since drug treatment is a factor that can be influenced, it is important to increase awareness of the associations between drug treatments, both as predisposing and precipitating factors, and falls. One clinical dilemma is that antidepressants and anticonvulsants are often clinically essential, benzodiazepines and other sedatives however are often avoidable.

In recurrent fallers, treatment with antidepressants (SSRIs), a history of falls, older age and an inability to bath without assistance were the factors most strongly and independently associated with being a recurrent faller. Recurrent fallers probably have more stable predisposing risk factors for falls, indicating in this study too (Paper I), the importance of antidepressants and functional impairment.

**PRECIPITATING FACTORS**

Because of the frailty of the elderly, acute diseases, often commonplace and treatable, seem to be very important precipitating factors for falls among those living in residential care facilities and the risk-factor profile with increased susceptibility is probably one explanation for this.

In Papers I and II, 32% (including vertigo) and 39% respectively, of the falls were judged to
be caused by acute diseases or symptoms of diseases which is an even higher proportion than in earlier studies (20, 39, 46, 82).

Delirium, the most frequent precipitating symptom in Paper II, is by definition usually a symptom of an underlying disease. However, it was frequently impossible to determine the underlying causes of the delirium, which is also true regarding other symptoms such as anxiety. In a study aimed at the prevention and treatment of postoperative delirium, injurious falls were significantly reduced (109), which supports the finding that delirium is an important precipitating factor. In Paper I some symptoms, such as delirium, were not included in precipitating factors.

It should be possible to prevent or diagnose quickly many of the most common diseases and symptoms of diseases that precipitate falls and thus prevent them. One explanation for the higher proportion of acute diseases as precipitating factors in this study is probably the accuracy with which the falls were followed up.

Almost 8 or 9 % (Papers I and II) of the falls were judged to be caused by drugs, a proportion which seems to correspond with previous studies (20, 124). Benzodiazepines and neuroleptics were important precipitating factors alone, in combination with each other or in combination with other drugs and they accounted for 32 out of the 37 falls precipitated by drugs. These drugs have also previously been reported as important precipitating factors for falls among older people and should therefore be used with caution (123).

Sleeping medicine given at the wrong time and thereby causing falls, indicates that individualised dispensing of medicines could probably prevent some falls. This conclusion is supported by the fact that none of these 7 residents fell again, for the same reason, after adjustments to the dispensing of their medication.

Drugs as precipitating factors were mainly related to first-dose problems, but also to side effects linked to dose escalations. Some drug side effects are delayed, sometimes by several weeks, and it can be difficult to state with certainty that there is a correlation between the fall and the drug. This could indicate an underestimation of drugs as precipitating factors for falls. For instance, no falls in Paper II and only 3% of the falls in Paper I, were judged to be precipitated by antidepressants, which is surprising since antidepressants are a well-known predisposing factor for falls among older people (123, 127, 129, 131-133, 220), and a rather large proportion of the residents, especially among those who sustained a fall, had been prescribed antidepressants. One explanation could be that there might have been only a few new prescriptions during the study periods. Another explanation could be that the onset of side effects, like effects, may be delayed in antidepressants (123).
Consequently, many of the symptoms described could be, and probably are, symptoms of diseases or drug side effects that are never diagnosed as such.

*External factors* were judged to precipitate almost 8% of the falls in Paper II. In some studies 35%–45% of falls are attributed to home hazards,(27, 39, 78, 221, 222) but newer findings do not support this (23, 154) and case control studies have failed to find any association between environmental hazards and the occurrence of injurious or repeated falls in older people living in the community (153, 223). One explanation for the high proportions in some studies could be that when interviewed after a fall, older people might identify an environmental hazard as the cause, prior to internal causes (28, 78). Another explanation may lie in poor post-fall assessment not detecting acute diseases and drug side effects. Furthermore, external factors seem less important as precipitating factors among frail older people in institutions (112). In this study defective materials and obstacles account for the half of the external precipitating factors and it ought to be possible to prevent such falls to a greater extent.

*Other conditions*, such as errors of judgment/misinterpretation, miscalculation and misuse of walkers by the residents, are often related to the individual's reduced cognitive capacity and are often difficult to prevent. In the case of roller walkers more critical judgment and a better follow-up when placing one at a resident's disposal could prevent falls, since a walker may even be a precipitating factor for falls in residents with dementia. Mistakes made by the staff and the lack of adequate facilities could be the result of anything from ignorance and carelessness to understaffing. In addition, prevention of falls in people with cognitive impairment is probably best ensured through better supervision.

**WEATHER FACTORS**

There were no associations between falls and any of the weather parameters studied. Since the study mainly concerned indoor falls there is no expectation that slippery roads or pavements would influence the fall rates, which is probably the case for outdoor falls during November, December and January, but not in April and May, in this geographic area. In addition, associations between indoor falls and outdoor temperature and daily precipitation is less expected. Atmospheric humidity and air pressure, unlike for example musculo-skeletal symptoms and rheumatic disorders (165, 166, 170-172), were not associated with falls at all. Nevertheless the prevalence of hip fractures is the highest in this part of the world and is
higher in northern Sweden than in southern Sweden, possibly indicating some association with climate (224).

One might expect an association between falls and weather parameters to be mediated by the atmospheric influences on physiological mechanisms such as blood pressure, vasoconstriction / angina pectoris, pulmonary diseases, postural control and / or rheumatic pain. The possibility cannot be excluded that influences of weather conditions may contribute to the risk of falling indoors in some types of falls or fallers, for example falls in people with rheumatic pain, hypotension or heart disease, in frail older people or maybe in those who consider themselves to be sensitive to changes in the weather, but this could not be analysed in this study (Paper V).

**METHODOLOGICAL CONSIDERATIONS**

The definition of a fall used in this thesis was chosen based on the judgement that this definition is less difficult to use when studying falls in frail older people, especially those with cognitive impairment than other definitions. It also better reflects the problem met in clinical practice.

In Paper I the staff filled in a fall report and the falls were followed-up by a nurse who was part of the permanent staff as well as being employed part-time on the project. In Papers II and V the fall reports, filled in by the staff, were collected once a week by a physiotherapist who was a member of the research team. The resident’s charts were also reviewed by members of the research team to complete the reports. Up to 8 % of the falls were found in this way, even better than the findings in the FICSIT studies (225) where it was found that 10-15% of the falls were missed when relying on fall incidence reports.

The incidence of falls nevertheless represent minimum figures, since some falls are never reported, a situation most common in the case of demented people. The only certain registration of falls would be camera supervision, which is out of the question for ethical reasons. Information about the number of days the residents are at risk of falling increases the accuracy of estimations of the incidence rates of falls in Papers I, II and V.

The follow-up of falls was careful in Paper I, but it was developed even further in Paper II. The careful post-fall assessment of the faller, including a high proportion of fallers
undergoing x-ray examination, is probably one explanation for the rather high proportions of injurious falls and fractures in Papers I, II and V. For example one patient’s trochanteric fracture was not detected until she was examined by x-ray for the fourth time (Paper I). Yet the fracture incidences reported may be an underestimation, as older people treated with analgesics might only have minor symptoms from a fracture. The injury registration in Paper V and to some extent in Paper II, is less certain than in Paper I, since the fallers were not assessed by a physician unless the nurse suspected a serious injury.

The prospective follow-up of falls (Papers I, II and V) is to be preferred to the retrospective recording of falls often used in earlier studies (36, 37, 226), since older people have difficulties in recalling earlier falls and the circumstances under which they occurred (85). In addition, environmental factors are probably overrated since the individual older person has less opportunity to detect and evaluate risk factors associated with her/himself – internal factors (28, 78).

There was no prospective follow-up for falls in Papers III and IV, but one advantage they offer is the opportunity to study a larger population. The sample was large enough to allow analyses of common drugs and subgroups of drugs such as, for example, antidepressants and neuroleptics. Several other groups and subgroups of drugs were registered but too few residents were treated with them to allow for reliable statistical analyses. Even larger studies are needed to analyse rare groups and subgroups of drugs.

Another advantage is the close connection in time between the factors studied and falling, making the associations more reliable. For example, there are a fairly long follow-up period for falls in most studies (mainly 6-12 months) (8, 11, 13, 16) with almost no check on the drugs prescribed at the time of the current fall. In Papers III and IV the drugs prescribed were those given at the time of the fall, with exception of possible changes during the days immediately preceding the fall, which may be one explanation for the differences between the current findings and those in previous studies.

Results from univariate analyses are less important than those obtained when the factors are subjected to multivariate analyses, since the risk of confounding matters is reduced. However, when multivariate analyses are performed true associations may go undetected due to strong statistical correlations between variables, not always of clinical or biological relevance. For example, cognition and ADL function are strongly correlated but have differing impacts on the risk of falling, as previously discussed.
Based on the assumption that risk factors for falls may be both more chronic, predisposing factors and acute, precipitating factors, the aim in this thesis was to analyse both types of risk factors. In accident-prevention research in general analyzing the accident scene, the accident situation and the aetiology of the accident are fundamental (87, 227, 228). This also supports the assumption that it is important to analyze the circumstances prevailing at the time of falls in older people.

The post-fall assessments and conferences were further developed in Paper II. The judgement is that the cooperation of the various competences together evaluating the falls in Paper II has resulted in valid judgments regarding precipitant factors for the falls despite the fact that the evaluation of a precipitant for a fall will always include some degree of subjectivity.

Paper II was part of an intervention program that resulted in a significant reduction in the number of fallers, falls, and hip fractures (31). The intervention program consisted of both general and resident-specific, tailored strategies comprising educating the staff, treatment of detected diseases, reviewing drug regimens, modifying the environment, implementing exercise programs, supplying and repairing aids, providing free hip protectors, having post-fall problem-solving conferences and guiding the staff. This poses a methodological problem, since the follow-up of the falls led to an intervention to prevent further falls. This means that these studies, if anything, underestimate the number of falls (Papers I, II and V) as well as precipitating factors for falls (Papers I and II). Nevertheless, it cannot be stated with certainty that possible precipitating factors for falls, such as postprandial hypotension, syncope and carotid sinus hypersensitivity, were not overlooked or under-diagnosed, especially in frail cognitively impaired residents or they may be the result of some factors not assessed for.

In Paper V one explanation for there being no associations between weather parameters and falling, could be that we did not analyze different groups of falls, i.e. falls caused by defined predisposing, precipitating, intrinsic or extrinsic factors, or fallers, for example demented and non-demented. On the other hand our experience is that while in many cases a single fall can be given a cause there are so many causes leading to falls that on the aggregate level the number of falls seems to be a random phenomenon.

**ETHICS**

Studying frail older people has to be preceded by ethical considerations. Ethics must always be considered not only before the start of the project but also while it is proceeding. Effective
treatments may not be withheld, if available, from anyone who needs them. Some steps forward in fall prevention are made in intervention studies, but no older people in these studies have been denied any prevention strategies already introduced in the clinical treatment and nursing in the settings studied.

The ethical consideration is crucial when studying people with cognitive impairment or a dementia disorder, since they cannot consider the matter of participating. However, this group of older people also deserve good and evidence-based medical care and nursing, which is why it is very important to include this group in research. So, there are two important ethical conflicts. First, although vulnerable older people must be protected, protection should not prevent research on this important population (229). In Papers I, II and IV, the residents, or in case of dementia sufferers the relatives, gave their consent after oral and written information. In Papers III and IV, which are population-based studies, the data were considered as register data, since they were based on clinical observations by the staff and medical charts regarding drug prescription. No personal particulars were collected and the goal was to analyze statistical associations between different variables in a selection of the population. Support for not obtaining the residents’ individual consent is found in the law concerning personal details in Sweden (1998:204, §19). All studies were approved by the Ethics Committee of the Faculty of Medicine at Umeå University.

**PREVENTION**

The risk of falls and injuries in the population of frail older people in geriatric care settings is high and should be targeted for prevention without delay. In this group of frail older people with a lot of risk factors it is probably multifactorial, interdisciplinary preventive strategies, as individualised as possible, that are needed. Studies II and V were parts of an intervention program that resulted in a significant reduction in the number of fallers, falls, and hip fractures (31). The intervention program consisted of both general and resident-specific, tailored strategies comprising educating and guiding the staff, treatment of detected diseases, reviewing drug regimens, modifying the environment, implementing exercise programs, supplying and repairing aids, providing free hip protectors and having post-fall problem-solving conferences. The post-fall problem-solving conferences represent one strategy that differentiates the current successful intervention study from other previously published less successful randomized fall-prevention studies in residential care (189, 230-233). This indicates that this activity might be an important part of a fall-prevention strategy. Fall-
prevention in older people in residential care is complex and demands great knowledge and skills on the part of the staff. Fall-prevention programs improperly performed might even increase the risk of falling (234).
GENERAL CONCLUSIONS

- Falls and fall-related injuries in older people in geriatric care settings are common.

- Both predisposing and precipitating factors contribute to the risk of falling. Decline in functional ability (gait, mobility and ADL) and cognition and treatment with antidepressants, are the most important predisposing factors for increasing the risk of sustaining falls as well as a history of falls, the marker of people at increased risk of falling.

- In the group of cognitively impaired older people behavioural and psychiatric symptoms are also important predisposing factors for falls.

- In frail older people with a lot of predisposing factors, precipitating factors often push the person over the fall threshold. Important precipitating factors are acute diseases and drug side effects from psychoactive drugs but also external and other factors related to both the environment and the individual.

- Weather parameters may influence humans in some ways, but were not shown in this study to be associated with falls in the population of older people in residential care.

CLINICAL IMPLICATIONS

Falls and their consequences in older people are a part of everyday working life for all professionals in geriatric care. Both general and individualized interventions are important in any preventive efforts and a fall-prevention program should be interdisciplinary with a multifactorial approach. Identification of risk factors serves as a useful tool in the selection of high-risk populations and provides a framework on which to structure an intervention. Increased knowledge about risk factors for falls and possible preventive measures among all who work with these older people is crucial, but not sufficient in itself.

The most fall-prone older people have to be identified immediately and questions about any history of falls is probably very useful. To increase the individualization of the prevention strategies, post-fall assessments and conferences should be held on a regular basis, to identify both important predisposing factors and the precipitating factors prevailing at the actual fall. Changes in health are common in this population and many benefits are probably to be gained
from ensuring that the staff is aware of the risk of sustaining falls during acute diseases and when new drugs are prescribed. The keen ear of staff to changes in the older person’s health and symptoms should be encouraged to allow treatments to be started or medical drug prescriptions to be changed before a fall occurs.

An educated and sufficiently large nursing staff is essential, not least in the care of cognitively impaired older people, if falls are to be prevented. Prevention and treatment of behavioural and psychiatric complications are probably a necessary part of any preventive program for older people with dementia.

When prescribing a new drug the physician should always consider the drug both as a possible predisposing and/or a precipitating factor for falls. The physician should also be aware of the importance of preventing, diagnosing and treating acute diseases and symptoms of disease in the effort to prevent falls.

In frail older people especially multifactorial, interdisciplinary preventive strategies, which are as individualised as possible, are probably prerequisites for successful fall prevention.

It is a self-evident, that as falls are common, immediate efforts to prevent fall-related injuries, not least fractures, are required. From this perspective the prevention and treatment of osteoporosis and the use of hip protectors have to be mentioned.

**IMPLICATIONS FOR FUTURE RESEARCH**

Discrimination on the basis of age is not only ethically unacceptable in a society that embraces the principles of justice and equity, but is also not supported by scientific and/or economic analyses (235). Therefore continued research into older people and the threats to their health, for example falls, are very important.

Predisposing and precipitating factors for falls are rather well mapped out, but questions remain concerning factors probably affecting the risk of falling, such as delirium and vertigo/dizziness, that have to be studied further in larger samples. The prediction and prevention of falls are studied continuously, yet one of the challenges for future is still to be able to prevent falls and fall-related injuries in older people, both those living in the community and those living in institutions with and without cognitive impairment.
Furthermore, health economic analyses of fall-prevention efforts are needed in a world where resources cannot meet the needs.

New pharmaco-epidemiological studies are needed in the future in various groups of older people to be able to detect new drugs that are predisposing and precipitating factors for falls and injuries. New drug trials and systematic reviews of drugs, not least those acting on the central nervous system, should include the incidence and severity of falls as secondary outcome measures. This is also beginning to happen. Furthermore, the effects and side effects of new drugs in general, especially on older people, should be evaluated before they are registered for use.

Fall-prevention studies in the group of older people with dementia have previously failed. Future research has to include prevention and treatment of behavioural and psychiatric complications in prevention studies in older people with cognitive impairment.

Future research should focus on making prevention programmes most cost effective by directly assessing exactly which components of multifactorial fall risk assessment and what characteristics of, for example, exercise programmes are essential. There is also a need to target people who are most likely to benefit. At present information of this kind is not available.

In summary; for any strategy to be effective and of direct relevance it should be shown to be acceptable and applicable to the relevant population, to reduce falls and fall-related injuries and to be readily applicable to everyday practice. Prevention of falls reduces fall-related injuries and suffering and can probably reduce costs to society. Further research has to focus on and evaluate the cost-effectiveness of various fall-prevention programs, in order to achieve the greatest benefit from the limited resources available.
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