Falls, perceived fall risk and activity curtailment among older people receiving home-help services

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FALLS, PERCEIVED FALL RISK, AND ACTIVITY CURTAILMENT AMONG OLDER PEOPLE RECEIVING HOME-HELP SERVICES

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To me and my family
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ABSTRACT

Falls and fall-related concern and fear of falling are not well understood when it comes to old people receiving home-help services, a transitional population in-between those living independently in the community and those living in residential care facilities. The psychological distress attributable to the perceived risk of falling among this population needs further exploration, which is also the case regarding possible ways to increase their feeling of security.

The aims of this thesis were to investigate the incidence of falls, fall-related concern, fear of falling and fall-related activity curtailment amongst older people receiving home-help services, as well as exploring the validity and user expectations of an automatic fall detector and alarm prototype. In a one-year prospective cohort study of 614 home-help recipients in one municipality in northern Sweden, the fall incidence was estimated to be 626 (95% CI: 479 – 773) per 1,000 person-years. The fall risk was significantly associated with receiving help for personal ADL needs: IRR 2.8 (95% CI: 2.1 - 3.8). An unexpected finding was that the fall incidence was significantly correlated to the amount of daylight (r: -0.78, r²: 0.61; p: 0.003).

A cross-sectional study of 51 home-help recipients in three municipalities in northern Sweden revealed that 65% (95% CI: 52% – 78%) had a high degree of concern about falling according to the Falls Efficacy Scale International (FES-I). This concern was significantly associated with concern about the consequences of falling, mobility and morale, but its correlation to fear of falling was moderate. The proportion reporting that they needed assistance to perform a specific activity or avoided one owing to a fear of falling was 57% and 26%, respectively. Such fear-dependent need for assistance was associated with morale and mobility, and fear-dependent activity avoidance with morale and fall-related concern.

While wearing a fall sensor attached to their hips, twenty middle-aged people performed six different intentional falls. For reference, these people, and 21 older people from a residential care unit, walked through a sequential ADL track. The results showed that the sensor could discriminate various types of falls from daily life activities with a sensitivity of 97.5% and a specificity of 100%. When the principle of the automatic fall
sensor and alarm system were described for them, 74% of the 51 elderly home-help recipients stated that it would increase their security, 66% that it would decrease their fear of falling and 57% that it would increase their freedom to move about, while 28% feared it could influence their privacy.

In conclusion, falls and fall-related concern seem to be common amongst the elderly recipients of home-help services, and this should be taken into account when planning the provision of services. Mobility, concern about the consequences of falling and morale seem to be connected both with a concern about falling and fall-related activity curtailment. Furthermore, a fall detector system has promising potential for use among home-help recipients. The correlation between the incidence of falling and the amount of daylight should be further explored.
SVENSK SAMMANFATTNING

Fall och oron för att falla är inte väl studerat bland äldre personer som bor i ordinärt boende och har insatser från hemtjänsten.

Syftet med denna avhandling var att studera incidensen av fallolyckor, fallrelaterad oro och fallrelaterade aktivitetsbegränsningar bland äldre personer som har hemtjänstinsatser. Vidare var syftet att dels studera med vilken precision en automatisk fallsensor kan identifiera fall och dels förväntningarna på nämnda sensor bland äldre personer med hemtjänstinsatser.

Under ett år studerades förekomsten av fall hos totalt 614 äldre hemtjänstmottagare i en kommun i norra Sverige. Förekomsten av fall beräknades vara 626 (95 % CI: 479 – 773) per 1000 person-år. Fallförekomsten var signifikant associerad till insatser för personlig ADL: IRR 2.8 (95 % CI: 2.1 – 3.8). En oväntad upptäckt var att förekomsten av fall var signifikant korrelerad till dagsljusets längd under året (r: -0.78; r²: 0.61; p: 0.003).

En tvärsnittstudie av 51 äldre personer med hemtjänst insatser i tre kommuner i norra Sverige visade att 65 % (95 % CI: 52 % – 78 %) upplevde sig vara mycket oroade för att falla, skattad med mätinstrumentet Falls Efficacy Scale International (FES-I). Oron var kopplad till mobilitet, morale (kampanda) och bekymmer för möjliga konsekvenser av ett eventuellt fall.

Andelen som rapporterade att de på grund av rädsla för att falla behövde assistans för att genomföra en aktivitet eller undvek en specifik aktivitet var 57 % respektive 26 %. Assistansbehov på grund av rädsla för fall var associerad med morale och mobilitet och avstående av aktiviteter var associerad till morale och oro för att falla.

Sex olika avsiktliga fall genomfördes på en mjuk matta av tjugo medelålders personer vilka bar en fallsensor i ett bälte placerad vid höften. Vidare genomförde ovan nämnda personer samt 21 äldre personer från olika äldreboenden en bestämd serie vardagliga aktiviteter. Resultatet visade att sensorn kunde skilja mellan avsiktliga fall och vardagliga aktiviteter med en sensitivitet på 97.5% och specificitet på 100 %. Av 51 äldre personer med hemtjänstinsatser svarade 74 % att ett automatiskt fallarm byggd på en sådan sensor skulle öka deras säkerhet, 66 % att det skulle minska rädslan för att falla och 57 % att det
skulle öka deras rörelsefrihet. Att det skulle göra intrång på deras privatliv fruktades av 28%.

Slutsatsen är att fall och fallrelaterade bekymmer är ett vanligt förekommande fenomen bland äldre personer med hemtjänstinsatser och borde beaktas när insatsen planeras. Mobilitet, morale samt bekymmer för konsekvenser av ett eventuellt fall verkar vara kopplad både till oro för fallolyckor och till begränsningar i aktiviteter på grund av fallrisk. Automatiska fallarm visar på en lovande potential för att öka tryggheten för äldre personer med hemtjänstinsatser. Korrelationen mellan förekomst av fall och dagsljusets längd under året bör utforskas vidare.
ABBREVIATIONS

ADL: Activities in Daily Living
FES-I: Falls Efficacy Scale-International
I-ADL: Instrumental Activities in Daily Living
IRR: Incidence Rate Ratio
MMSE: Mini-Mental State Examination
P-ADL: Personal Activities in Daily Living
PGCMS: Philadelphia Geriatric Center Morale Scale
PY: Person-Years
SPPB: Short Physical Performance Battery for lower extremity
LIST OF ORIGINAL PAPERS


Reprints were made with kind permission of the International Association of Circumpolar Health Publishers (Study I) and the Elsevier Limited (Study II).
INTRODUCTION

Ageing, disability, and home-help services

The proportion of older people aged 60 year and older is growing in most countries in the world, and is expected to continue growing more rapidly until at least 2050, and the fastest growing population is people 80 years and over (1). In Sweden, around 18 % of the Swedish population had passed the minimum retirement age of 65 years and over in 2009 and for people of 80 years and over the proportion was 5% (2). In the year of 2060 the proportion of older people 80 years and over is expected to reach almost 1 million, corresponding to approximately 9 % of the Swedish population (1).

In general the need for personal assistance increases along with the aging process, and after the age of 80, it becomes increasingly common for people to need support in performing daily living activities (ADL) (3), starting with dependency in the instrumental activities of daily living (I-ADL), followed by dependency in personal activities of daily living (P-ADL) (4). The Statistics Sweden Surveys of Living Conditions (5) state that, between 1988/89 and 2002, the proportion of people needing help with ADL decreased for those of 65 years and older, however, during the same time period, the number of persons with great needs, defined as needing help with both I-ADL and P-ADL, increased to some degree. Similar trends have been reported among older people living in the United States (6). In the very old section of the population, one study, including people of 85 years and older, conducted in the north part of Sweden, reported half of the participants to be dependent for ADL (7).

Within the aim to enable older people to live at home the Swedish municipalities are, according to the Social Services Act (8) responsible to provide services in form of home-help for older people. The most important predictor of use of home-help seems to be dependence in ADL (9, 10). Other needs factors reported associated to home-help use are advanced age, living alone and cognitive impairments (10-12), and the amount of home-help are strongly connected to mobility limitation and cognitive impairments (10). The number of older people receiving elderly care has been basically stable since the year 2001. Simultaneously, the number of old people living in residential care has decreased
and the number of old people receiving home help services has increased (13). During the 2000s the proportion of home-help users, in the age-group 80 years and older have increased from 18 % in the year 2000 to 22 % in 2008 (14). This indicates that many of the old individuals receiving home-help services constitute a transitional group between independent community living old people and people in residential care, and that there is a trend towards a greater resemblance between home-help receivers and the latter group.

The home-help includes assistance with P-ADL, I-ADL, social support, and for family members who take care of their old relatives support and relief services can be provided. The Swedish home-help system also offers home-help around the clock. Furthermore, beside regularly visits of home-help staff, persons can be offered security alarm system, which are usually linked to an alarm center where personnel respond and attend to alarms they receive (15).

**Falling**

Falls are common among older people and for many of them a fall can have a significant impact on health and threaten independence and quality of life (16). As a result of a fall-related injury, many old people will transfer from independent living to dependence, needing assistance performing ADL activities (17, 18).

**Definition**

Falls have been defined differently over the years. In the late 1980s, the Kellogg 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 other lower level and as a consequence of the following: sustaining a violent blow, loss of consciousness, sudden onset of paralysis, a stroke, and an epileptic seizure” (19). In a systematic review, The Prevention of Falls Network Europe (ProFaNe) suggests a fall be defined as “an unexpected event in which the participant comes to rest on the ground, floor, or a lower level” (20). In this thesis, a fall is defined “as an event in which a person, unintentionally and regardless of
cause, comes to rest on the floor or another lower level”, the definition previously used in studies considering falling among people in residential care facilities (21).

**Incidence**

In community-dwelling older people of 65 years and older, approximately one third (22, 23) and about half of those aged 80 years and over, fall at least once annually (23). About half of the fallers will experience multiple falls within a year (22).

In order to describe how common falls are in different populations, rather than the percentage of people having suffered falls during a specific period of time, the incidence rate of falls often are calculated. For community living people, the incidence rate for falls has been estimated to be 517 per 1,000 person-years (PY) (22) and, 683 per 1,000 PY (24). Among people living in residential care facilities, the corresponding figure is estimated to be three times higher (21, 22). The frequency of falling increase with age, being female (23), and having functional limitations (25, 26). The location of falls is also related to age, sex and frailty. Frail old people suffer more falls within their homes compared with vigorous people, who seem to fall more frequently outdoors (24, 27).

The fall incidence among people receiving home-help services has not been established to the best of our knowledge. As described previously, this population presents a high prevalence of mobility limitations and impairments and seems, in many respects, to be a transitional population in between being independent older people and older people living in residential care. The only accessible figures are derived from two retrospective studies concerning populations similar but not identical to older home-help receivers. Fletcher et al (28) reported over a 90 day period that 27 % of home-care receivers had fallen and, in a retrospective case-control study, Lewis (29) reported that 6 % of individuals receiving home health services during a single year suffered falls.

**Risk factors**

Falls are a multi-factorial problem, and risk factors contributing to falls have been studied to a great extent and a number of factors, about 400 in total have been identified and are described in the literature (30). The evidence points towards falling being caused by a combination of predisposing factors (intrinsic) and precipitating factors (extrinsic and
environmental). The most frequently reported risk factors are advanced age (22, 23, 31), having a history of falling (23, 32), gait and balance impairments (23), cognitive impairment (32) and fear of falling (33, 34). Regarding precipitating factors, drugs (35) and environmental hazards are the most commonly reported risk factors (36).

Seasonal variation

The association between seasonal conditions and the occurrence of falls has been studied to some extent. A seasonal variance in hip fracture incidence, with a higher incidence connected to winter conditions, has been reported in several studies (37-40). Regarding fall incidents, no consistent pattern of seasonal variation has been found among old people in residential care in Sweden (21), nor has such a variation been found regarding injurious fall among community living old people in Finland (41). On the other hand, among community living people aged 70 and more, Luukinen et al (42) demonstrated a higher fall incidence of outdoor falls connected to extreme cold periods, and Campbell et al (43) showed an association between low temperatures and fall incidence among women.

It is reasonable to think that among older people living at high latitudes there are specific factors that could contribute to a seasonal variation in falling. The level of thyroid hormone and serum melatonin among people taking part in Antarctic expeditions has been found to be significantly correlated with the amount of daylight (44), and among out-door workers living in a sub-arctic region, the highest serum thyroid level was found in December (45). In a population-based study of older people, aged 85 years and over, living in the northern part of Sweden, thyroid disorders were found to be an independent explanatory risk factor for falling (7). Furthermore, melatonin is a hormone closely linked to the circadian rhythm (46).

Consequences

Falls are reported to be the leading cause of injury-related hospitalization (47) and injury-related death (48). Around 40-60 % of falls lead to injuries, with 30-50 % being minor (49) and approximately 10 % being classified as severe injuries, including fractures and head injuries (23, 27). However, additional to the physical consequences, anxiety about
falling again (33) and remaining on the ground or floor unable to get up (50-52) are significant psychological stressors related to falls.

**Perceived fall risk and consequential activity curtailment**

Perceived fall risk can be seen as an ongoing concern about falling (56), and has been assessed using several different single- and multiple-item instruments indicating either fear of falling, fall-related self efficacy, balance confidence, or fall-related concern (53). Single-item assessments have frequently been used, presumably because they are easily administered, directly and head-on, and have a certain degree of face validity. On the other hand, the use of a single-item question measuring the perceived risk of falling has been questioned because it may report a general fear (55), and a single question might not be able to predict actual functioning and behavior. The multi-item questionnaire Falls Efficacy Scale (FES) is intended to measure a person’s confidence in his or her ability to avoid falling when undertaking ADL activities (54), and the Falls Efficacy Scale International (FES-I) focuses concern about falling when performing ADL, including outdoor and social activities (57). In this thesis FES-I and a single question are used to assess perceived fall risk.

Concern about falling is prevalent regardless a fall history or not, although the prevalence seems to increase with the experience of falls. Among independent community living older people with no fall history the prevalence is estimated to range between 12 % and 65% (58), and for older people with a history of falls, the prevalence rate is reported to be between 29 % and 92% (55, 59). This considerable variety in prevalence rates are likely due to different definitions and instruments used, as well as different populations studied. The prevalence is higher among women and increase with advancing age (60). Half up to two thirds of older people living in senior housing are reported to be fear falling to some degree (61, 62). In a study among frail old people enrolled in a long-term care program, delivered in a variety of settings including the people’s own homes and skilled nursing facilities, 48 % reported to fear falling (63).
The etiology of fear of falling, fall-related efficacy, balance confidence and fall-related concern is complex and multifactor and several factors are identified to be associated to these phenomena. Mobility limitation is in several studies reported independent associated to fear of falling (62, 64, 65). Other factors associated are female sex (67), fall history (33, 60, 67, 68), feelings of unsteadiness (60), ADL limitation (66), poor self-rated health (55), depression and anxiety (69, 70), neuroticism (71), decreased quality of life (34, 68 72) and life dissatisfaction (68).

Cumming (34) found low falls efficacy to be associated to decline in ability to perform ADL without assistance, and in fact, increased the risk for future falls. Although, it seems reasonable that some degree of concern may be rational and have a possible preventive effect (73), there is a growing consensus that high level of concern about falling is dysfunctional and may lead to the curtailment of activities (64, 74, 75). This behavior may in the long-term result in a circle of frailty including loss of physical functions such as reduced muscle strength, decreased postural control and increased fall risk (76), and decreased quality of life (68). A study including home-care recipients, reported 41 % of the recipients to restrict activities because of fear of falling (77). Similar prevalence rates are reported in population-based studies among community living older people (66, 67, 78).

Being alone for long periods of time during the day, mobility limitations and multiple falls are factors significantly associated to such activity restrictions (64, 66, 77). Other factors related to activity restriction are high age (66), and poor self-rated health (78). Restricting several activities (three or more) seems to be associated to I-ADL dependence and lower limb dysfunction. (75). The number of curtailed activities (79), and degree of support to cope with ADL activities (80), seems to follow the degree of perceived fall risk. Support from family members or relatives seem to be an important factor for continuing to remain active even in the case of perceived fall risk. (74).

When studying factors associated with perceived fall risk, and subsequent activity curtailment, some factors previously not studied in this respect could be of interest.

Morale may be a factor influencing perceived fall risk (82). This is based on findings by Delbaere (81) who describes that some older people, despite a high physiological fall risk, rate their self perceived fall risk as low. These people seem to have a positive out-
look on life, and a high quality of life. In the opposite, some older people with low physiological fall risk, rate their self perceived fall risk as high, and these people are reported to have decreased quality of life and more depressive symptoms. Morale is a construct often used synonymously with psychological well-being, quality of life and life satisfaction (83), and reflects an individual’s perception of physical and mental health (84). The construct is defined as “a basic sense of satisfaction with oneself, a feeling that there is a place in the environment for oneself and a certain acceptance of what cannot be changed” (82). The Encyclopaedia of Gerontology (85) adds to the definition “a future-oriented optimism or pessimism regarding the problems and opportunities associated with living and ageing”. Semantically, morale is synonymous to confidence, self-esteem and drive.

In a risk-theoretical approach Slovic et al (86) describe risk perception as a process of two parallel systems, a cognitive and an affective one, working together in what is called a “dance of affect and reason”. From this perspective, reasoning would be the cognitive system calculating the probability of the risk and affect would be the feelings induced by thoughts of the eventual consequences. In line with this, it is reported that many old people fear the possible devastating consequences a fall might have, regardless of whether they have experienced a fall or not (87, 88), and catastrophic thoughts of this type seem to mediate a concern about falling, with a subsequent mobility restriction. This opens up the possibility of including both perceived probabilities of the fall risk and concerns about the consequence of an eventual fall when studying perceived fall risk.

**Preventions that reduce falls and the perceived fall risk**

As described, falls and the perceived fall risk multifactor pervasive problems among older people that can lead to detrimental consequences such as loss of independence, curtailment of activities, physical inactivity and reduced social engagement. Prevention is, therefore, of particular importance. Programs including exercises targeting strength, balance, flexibility and endurance demonstrate strong evidence for reducing the rate of falls and the number of people falling, as do multifactor programs (89). When it comes to
intervention aimed at reducing or preventing the perceived fall risk, the evidence is weaker. However, home-based exercise programs, practising Tai Chi, and multifactor intervention programs have been shown some effect (90). Furthermore, it should be considered that the perceived fall risk in part is mediated through thoughts and beliefs, and building on this, an intervention using a cognitive-behavioural approach demonstrated effects on fear of falling (91, 92).

It has been described that older people may be afraid of falling owing to the fear that they will remain lying on the floor or ground unable to get up (93). Automated fall detectors have been developed to facilitate the provision of early attention and to reduce the length of time spent lying on the ground following a fall. Thus, automated fall detection might be a possible measure for reducing some important aspects related to concern regarding falling, as experienced by old people. Different techniques have been used to identify falls automatically, mostly based on accelerometers attached to the body (94, 95). In previous studies, there are indications that fall detection using a waist worn tri-axial accelerometer and quite simple algorithms would be sufficient for accurate fall detection (96, 97).

**Rationale for this thesis**

Falls and the perceived fall risk are well-known factors that threaten older people’s safety and independence, leading to activity curtailment, which may, in the long term, lead to loss of functions and an increased risk of falling. Although, these phenomena have been well studied among older people, little focus has been paid specifically to older community-living people receiving home-help services. This population constitutes a transitional group comprised of those who are at a stage in life where they are between independent community living older people, and people living in residential care facilities. During the last decade the number of home-help recipients has increased, with a simultaneous decline being shown in the number of older people living in residential care. As the intention of the Swedish policies is for older people to age “in-place,” with high quality of life, and to grow old in security whilst retaining independence, it is of importance to under-
stand the risk of falling in this population. Also, it must be deduced that it is of interest to study factors related to concern about falling and fear-related activity curtailment among old people receiving home-help services.

Inspired by risk theoretical reasoning about cognitive and affective factors being involved in the perception of risk, it would be of interest to include both a person’s self-rated risk of falling, and concern about the consequences of falling, among the factors identified in previous studies, that one could expect to be associated with the perceived fall risk. Furthermore, it could be enlightening to study whether the construct morale, the definitions of which include both acceptance of oneself and of one’s place in the environment, as well as optimism about the future or pessimism regarding aging is related to the perceived fall risk. It seems reasonable that age-related self-esteem and expectations for the future would have an impact on the psychological processes underlying the perception of the risk of falling.

Beside the regular home visits made by home-help staff, older people are offered safety alarm systems to increase their sense of security. Today, most of these systems have to be activated manually by the person himself or herself, which might be impossible in the event of a fall. Therefore, efforts to develop reliable automatic fall detectors are required. A waist-worn tri-axial accelerometer using quite simple algorithms to detect falling has been developed, but needs to be validated regarding to determine its sensitivity at detecting deliberate falls and its specificity, i.e. its ability to not produce alarms during daily activities. Furthermore, user expectations need to be explored for the future development of such systems.
AIMS

The overall aim of this thesis was to study falls, perceived fall risk, and activity curtailment amongst older people receiving home-help services.

The specific aims were:

To investigate incidence, including possible seasonal variation of falls, and to investigate whether fall incidence is associated to type and amount of home-help services provided.

To describe fall-related concern as well as fear of falling, and to investigate which independent associations can be identified between fall-related concern and factors such as age, sex, mobility, cognition, morale, fall history, self-rated fall risk, and concern of the consequences of falling.

To describe how curtailment of the independent performance of specific activities of the FES-I relate to fall-related concern, and to describe how curtailment attributable to fear of falling while performing specific activities is related to a set of pre-selected individual factors.

To validate the data collection of an automatic fall sensor system by defining the sensitivity, and specificity of different fall detection algorithms, and to explore user expectations on such a device regarding its potential to increase self-perceived safety and security.
METHODS

This thesis is comprised of four studies: one prospective cohort study, and three studies using a cross-sectional design. An overview over this research is presented in Table 1.

<table>
<thead>
<tr>
<th>Study</th>
<th>Design</th>
<th>Participants, n</th>
<th>Main objectives</th>
</tr>
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<tbody>
<tr>
<td>I</td>
<td>Prospective cohort</td>
<td>Total, n= 614</td>
<td>Incidence of falling</td>
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<td></td>
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<td></td>
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<td>II</td>
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<td>Female, n= 39</td>
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</table>

Participants and settings

_Study I_ and _Studies III – IV_, were conducted in four municipalities located in the north of Sweden and included people aged 65 and over, receiving regular home-help services for some period of time, regardless of whether it is long or short.

_Study I_, was conducted over one year in one municipality in the north of Sweden, and included a total of 614 participants with a mean age of 81.8 ± 6.8; 67 % were women, with a median value of 4.75 hours/week (Q1, Q3: 2.0, 12.3) of home-help services being
provided. The participants were identified through monthly reviews of the home-help service records. Median time in the study (exposure time) was 304 days (Q1, Q3: 132, 365), and 270 participants were followed for one full year.

In Studies III - IV, 184 randomly selected recipients of home-help services in three municipalities in the north of Sweden, were considered for invitation to participate. Staff familiar with the old people receiving the home-help services judged 24 of the individuals (13 %) to be unfit to participate, either because they were receiving palliative care or because they were disturbed or worried easily by visits from unfamiliar people. The remaining 160 individuals were invited to participate, of whom 79 (43 %) declined, 12 (7 %) ceased receiving home-help services, 10 (5 %) moved, 6 (3 %) died, and 2 (1 %) were not available. Thus, finally 51 (28 %) participated, which exceeded the minimum number of 46 to achieve the desired statistical power. Those who took part in the investigation did not differ significantly from those who did not in terms of their sex (p=0.12), age (p=0.40), and the weekly amount of home-help services received (p=0.22). The characteristics of the participants are presented in Table 2.

The data collection in Study II was arranged at the Luleå University of Technology, and at three residential care facilities. Twenty middle-aged persons working at the university were consecutively recruited into the study. Among the older people living in or participating in activities in residential care facilities, 21 persons meeting the inclusion criteria of being able to walk 10-meters with or without walking aids, were consecutively included. The persons were identified by physiotherapists and care staff who worked at the respective residential facilities. The mean ages of the groups were 48.4 and 82.2 years, and the mean self-paced gait speeds were 1.43 m/sec. and 0.75 m/sec., respectively.
Table 2. Characteristics of participants (n=51) in Studies III-IV.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean ± SD</td>
<td>82.8 ± 6.4</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12 (24)</td>
</tr>
<tr>
<td>Female</td>
<td>39 (76)</td>
</tr>
<tr>
<td>Living alone, n (%)</td>
<td>41 (80)</td>
</tr>
<tr>
<td>Home-help services h/week, md (Q1, Q3)</td>
<td>3.4 (1.0, 8.9)</td>
</tr>
<tr>
<td>Barthel index of ADL (0-20), md (Q1, Q3)</td>
<td>19 (17, 20)</td>
</tr>
<tr>
<td>SPPB (0-12), mean ± SD</td>
<td>4.3 ± 3.0</td>
</tr>
<tr>
<td>Use of walking aid, n (%)</td>
<td></td>
</tr>
<tr>
<td>Indoors</td>
<td>25 (49)</td>
</tr>
<tr>
<td>Outdoors</td>
<td>43 (84)</td>
</tr>
<tr>
<td>MMSE (0-30), mean ±SD</td>
<td>26.2 ± 3.0</td>
</tr>
<tr>
<td>PGCMS (0-17), mean ± SD</td>
<td>12.0 ± 3.6</td>
</tr>
<tr>
<td>Falls reported in previous 6 months, n (%)</td>
<td>23 (45)</td>
</tr>
<tr>
<td>Fall-related injuries reported in previous 6 months, n (%)</td>
<td>15 (30)</td>
</tr>
</tbody>
</table>

SPPB: Short Physical Performance Battery  
MMSE: Mini-Mental State Examination  
PGCMS: Philadelphia Geriatric Center Morale Scale

Data collection and assessments

The data collection for Study I was carried out during one year from October 2005 to September 2006, Studies III-IV were carried out between September 2009 and May 2010 and the data collection for Study II was completed in about one week in June 2007. An overview of the variables assessed in Studies I-IV is presented in Table 3.
### Table 3. Overview of variables assessed in Studies I-IV.

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Socio-demographical</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Sex</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Living situation</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekly amount of home-help services</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Type of home-help services</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Function, activity and health</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barthel ADL-index</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Short Physical Performance Battery, SPPB</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Walking speed</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Walking aid</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Mini-Mental Statement Examination, MMSE</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>The Philadelphia Geriatric Center Morale Scale, PGCMS</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Falls and fall-related injuries</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up falls 12 months</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Falls previous 6 months</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Fall-related injuries 6 months</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Perceived fall risk</strong></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Fear of falling</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Falls Efficacy Scale – International, FES-I</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Concern about the consequences of falling</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Activity curtailment</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Fall detection</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceleration data, intentional falls</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Acceleration data, ADL sequences</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expectations on automatic fall detection</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

**Study I**

In *Study I* the age, sex, type and number of hours of home-help services received per week were collected from the home-help service records. The outcome variable measured was falls and these were defined as events in which the person, unintentionally and regardless of cause, came to rest on the floor or at another lower level (20, 21).
The home-help service staff were instructed to report every event that came to their attention that met with the definition; a specifically designed fall report form was provided for this purpose. This methodology has been used previously in studies concerning falls in residential care settings (21). The report includes identification data for the person in question, the date, time, and location of the fall, as well as the ongoing activity. Consequences such as injuries and anxiety and measures taken after falls were registered on the report. As most falls are unlikely to be witnessed by the staff (98), the staff were instructed to gather as much information as possible from the individual concerned, or from other persons. The reports were sent to the researchers on a monthly basis.

**Study II**

In Study II, acceleration-related data were collected during intentional falls, and whilst performing sequences activities of daily living. The middle-aged participants wore a sensor attached with an elastic belt at the waist in front of the anterior superior iliac spine during the test session. Through the use of instructions and demonstrations, the middle-aged participants were instructed to perform two sets of six different falls which were intended to mimic typical fall events occurring among old people. The falls were referred to syncope, tripping, sitting on empty air, slipping, lateral falls and falls equivalent to rolling out of bed. All falls were performed from a podium or a bed onto a matress. All participants, both middle-aged and the old persons performed a sequential ADL protocol developed by the authors including 1) sitting down on a chair and getting up, 2) picking up an object from the floor, 3) lying down on a bed and getting up, 4) walking, including both walking on the flat and walking up and down stairs. The simulated falls and ADL sequences were documented using a digital and a video camera.

Each participant’s characteristics age, sex and self-reported fall history in the previous 6 months were gathered. Use of a walking aid indoors and outdoors was assessed, and each person’s gait speed was measured over 10 meters both at a comfortable speed and at the maximum speed. The test was repeated twice and the mean gait speed was calculated (99). The participants were allowed to use walking aids during the test if they were needed.
Study III - IV

In Studies III - IV, the assessments and interview were carried out in the participants’ homes by one of three assessors, all with long experience of assessing and examining old people. The information on the provision home-help services was gathered from the relevant home-help service’s records.

ADL were examined using the Barthel Index, which has been proven to be both valid and reliable (100). This instrument contains 10 items, scoring the degree to which it is possible for the person being assessed to control their bodily functions and to perform specific activities independently. Thus, it addresses such aspects as incontinence of the bowel and bladder, toilet use, grooming, dressing and bathing, feeding and transfer. The maximum total score of 20 indicates independent performance of all 10 items.

The Short Physical Performance Battery (SPPB) for lower extremity function was used to assess mobility (101). The assessment consists of three tests: standing balanced with feet in side-by-side, semi-tandem and tandem positions for 10 seconds, rising up from and sitting down in a chair five times without hand support; and self-paced walking speed over 2.4 m starting in standing position. Each test is scored on a scale from 0 (unable to perform the task) to 4, and summed to obtain a total score ranging from 0 to 12. The SPPB has been shown to be reliable and valid (102).

Data on the use of a walking aid indoors and outdoors was gathered (103).

The Mini-Mental Statement Examination (MMSE) (104) was used to assess overall cognitive function. This instrument is comprised of six categories: orientation, registration, attention and calculation, recall, and copying. The total score is 30 and scores below 24 have been suggested to indicate impaired cognition (105).

Morale was assessed by The Philadelphia Geriatric Centre Morale Scale (PGCMS), a questionnaire consisting of 17 items with yes/no responses, measuring the dimensions: agitation, attitude to own aging and loneliness-related dissatisfaction (82, 106). The total score ranges between 0 and 17, and it is suggested that a score between 13 and 17 indicates high morale, 10-12 middling morale and a score of 9 or below is indicative of low morale. This scale has been shown to have acceptable psychometric properties (107). In a Swedish study, the inter-rater reliability was shown to be satisfactory, with a coefficient
value of 0.86 (108), and the internal consistency coefficients varied from acceptable 0.81 (106) up to excellent 0.92 (109).

The participants were asked if they had sustained any falls or injury falls in the previous 6 months. Self-rated fall risk was assessed by asking the participants to rate the probability that they would fall within the next six months, with the responses “low” or “high”.

The participants’ attitude to falling was examined from two points of view: Fear of falling was assessed through the single question: “Are you afraid of falling”? with the response being made on a scale of 4 graded responses from 1: “No, not at all” to 4: “Yes, very much”. This simple method is commonly used to measure fear of falling in various populations (61, 66, 67). Fall related concern was assessed using the Swedish version of the Falls Efficacy Scale-International (FES-I) (57, 110). The questionnaire consists of 16 items related to simple and more complex indoor and outdoor ADL and social activities (e.g. bathing, dressing, climbing stairs, cleaning, shopping, walking on slippery or uneven surfaces and participating in social events). The items are scored on a four-point ordinal scale from 1: “not at all concerned”, to 4: “very concerned”, with the summed score ranging between 16 and 64. It is suggested that a score greater than 23 indicates a high level of concern about falling (111). The instrument has been demonstrated to have satisfactory to excellent psychometric properties. The usage of a test-retest procedure has resulted in intra-class correlation (ICC) coefficients ranging from 0.79 to 0.82 among old community-dwelling people of greater than 70 years of age living in different cultural contexts (112), and the Swedish version has proved to have excellent internal consistency, resulting in a Cronbach’s alpha of 0.95 (110). In Studies III - IV, the FES-I was interview administrated which is a method that is recommended for use when working with frail old persons (113). To make it easier during the interview the participants had a card with the different responses in front of them.

To assess the concern about the consequences of falling, the single question “If you were to fall, would you be concerned about getting hurt?” as inspired by the questionnaires “Consequences of falling” used in previous study (114). The question was answered on a 4-point ordinal scale, ranging from 1: “not concerned” to 4: “yes, very concerned”.

31
Inspired by the instrument Survey of Activities and Fear of falling in the Elderly (SAFE) (72), which, in addition to fear of falling, also assesses activity restriction in 11 activities arising from a fear of falling, the participants were asked to select the most appropriate response for each of 15 items in the FES-I. The item “Answering the telephone before it stops ringing” was excluded. For the activity in question, they were asked: “Do you perform the activity independently” = 1, “Do you perform the activity with assistance” = 2 or “Do you avoid the activity” = 3. Answering “with assistance”, or that they “avoid the activity”, the participants had to explain if the reason was because of “fear of falling” or “other reasons”. The number of activities performed “with assistance” because of fear of falling or “avoided” for the same reason, were summed up to obtain separate scores.

The participants answered questions regarding their expectations of automatic fall detection alarm, concerning whether it would increase security, reduce fear of falling, increase freedom to move around, and influence their privacy. The responses ranged from totally agree =1 to disagree =3. The questions were based on results from previous study (93).

**Statistical analyses**

The statistical analysis were calculated using the software package Statistical Package for the Social Sciences (SPSS®) version 15.0 and 17.0 in Studies I, III and IV. Stata software, version 10.0 (Stata Corp, College Station, Texas), was used in Study I and Microsoft Office Excel was used in Study II. A statistical significance level of 5 % (p<0.05) was used.

In all four studies, descriptive analyses were performed using standard statistical methods to match the scale properties of each variable assessed. The assessment instruments FES-I, SPPB, MMSE and PGCMS (Studies III-IV) were treated as ratio scales in the analyses as they are summary scores and as the data were approximately normally distributed. The weekly number of hours of home-help services received was analyzed non-parametrically because this data was skewed data (Studies I, III and IV). The correlation between FES-I and fear of falling (four grades of response) (Study III) was ana-
lyzed using Spearman’s rank correlation. For the calculation of incidence rates (Study I), the number of incidents occurring among individuals in the total sample or in sub-groups was divided by the individuals’ aggregated exposure time during the corresponding time period.

When calculating the sensitivity and specificity of the fall detection, data from all intentional falls and ADL sequences were combined across the participants, resulting in 240 fall samples and 164 ADL samples. The sensitivity was calculated as TP/(TP+FN) x 100, and specificity as TN/(TN+FP) x 100 where TP = true positive (detected falls), FN = false negatives (undetected falls), FP = false positives (ADL sequences resulting in false fall alarm), and TN = true negatives (ADL sequences not resulting in alarms).

A negative binomial regression model was used to relate the fall incidence to different types assistance received and to the amount of time allocated by the home-help services by calculating the effect on the incidence rate ratio (IRR) using 95 % confidence intervals. This method was used since it takes into account the dependence of events by the same individual and it is recommended for use in the evaluation of fall prevention (115).

Linear regression was used (Study I) to analyse how the seasonal variation in the incidence of falling (monthly incidence rates) was associated with the number of daylight hours for the 15th day of each month, or monthly mean temperatures, collected from the Swedish Meteorological and Hydrological Institute (SMHI) (116).

In Study III, a stepwise multiple linear regression model was used to analyse the association between age, sex, SPPB, MMSE, PGCMS, fall history, self-perceived risk of falling, concern about the consequences of falling (independent variables) and fall-related concern (dependent variable). The ordinal rating of concern about the consequences of falling was transformed into a dummy variable (with the reference: grade 1, “not concerned”). For Study IV, age, sex, FES-I, SPPB, MMSE, PGCMS, fall history, self-rated risk of falling, and concern about the consequences of falling (independent variables) were associated with the numbers of activities performed “with assistance because of fear of falling” and “avoided because of fear of falling” (dependent variables), respectively. The ordinal variable for the concern of fall-related consequences was dichotomized to “not concerned” (value 1) or “concerned” (values 2-4).
Ethical considerations

The research presented here has been approved by the Regional Ethical Review Board in Umeå (Dnr 05-150M, Dnr 09-131M).

In Study I, all data were based on authority records and fall reports and the home-help receivers studied were not asked for consent. From an ethical point of view, this is of course a disadvantage. On the other hand, this approach meant that data could easily be collected without requiring the personal involvement of the persons in study, which can be seen as an advantage considering the character of the data in this particular study. Participants in Studies II-IV gave their written informed consent. However, in Studies III-IV, in order to avoid the inclusion of old people who could be expected to be significantly disturbed or worried by visits from people unknown to them, and also home-help recipients receiving palliative care, we chose to ask staff to identify these group older people and they were never approached.

In Study II, the deliberate falls of course involved a risk for injuries. Therefore, participants were carefully informed about this, and the falls were performed on thick mattress, similar to the ones used in high jumping and participants wore wrist protectors. In Studies III-IV, all assessments and measurement procedures were chosen and adapted as to cause as little inconvenience as possible, considering the frail population in study. All three assessors were experienced in examining old people.

Participants in Studies III-IV might have appreciated being visited and having the possibility of expressing their view on falls, perceived fall risk, and activities.

In general terms, it was considered that the scientific gains that could be achieved by the studies outweighed the risks and potential inconvenience for the participants, especially as precautions hade been made in order to reduce such risks.
RESULTS

Fall incidence

In total, 264 falls occurred amongst 122 of the participants, corresponding to a fall incidence rate of 626 per 1,000 PY (95% CI 479 - 773). Almost all falls, 97% (247 out of 259), occurred indoors.

The fall incidence was significantly associated with receiving help for P-ADL needs or not: IRR 2.8 (95%: CI: 2.1 – 3.8). The total amount of home-help services received and the specific amount of I-ADL, P-ADL and escort/transport services allocated were significantly associated with a higher incidence of falling. Point IRR estimates indicated a 7% increased risk of falling per hour increase in the weekly allocation of home-help services. For I-ADL and P-ADL help services which accounted for a total of 80% of the total amount of services provided, the corresponding figures were 19% and 9%, respectively (Table 4).

Table 4. Relation of falls incidence to the types and amounts of different home-help services.

<table>
<thead>
<tr>
<th>Home-help services (hours/week)</th>
<th>IRR*</th>
<th>95% confidence interval</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total services amount</td>
<td>1.07</td>
<td>1.04 – 1.10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>I-ADL</td>
<td>1.19</td>
<td>1.11 – 1.28</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>P-ADL</td>
<td>1.09</td>
<td>1.04 – 1.15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Security/social support</td>
<td>1.08</td>
<td>0.96 – 1.22</td>
<td>0.213</td>
</tr>
<tr>
<td>Relief service in the home</td>
<td>0.75</td>
<td>0.49 – 1.14</td>
<td>0.178</td>
</tr>
<tr>
<td>Escort service</td>
<td>1.97</td>
<td>1.20 – 3.23</td>
<td>0.007</td>
</tr>
</tbody>
</table>

* Negative binominal regression. The total of services provided and the amount of each specific type of service provided are independent variables in separate bivariate analysis with falls as the dependent variable.
The monthly incidence of falling seemed to follow a rough sinusoidal curve (Figure 1), inversely proportional to the amount of daylight and the temperature during the year. The variation in the incidence of falling was significantly correlated to the number of daylight hours ($r$: -0.78; $r^2$: 0.61; $p$: 0.003), but not to the mean temperature ($r$: -0.51; $r^2$: 0.26; $p$: 0.090).

![Figure 1](image_url)

**Figure 1.** Monthly variation in the incidence of falling: The rate of falling plotted as a function of the month in which a fall occurred.

**Perceived fall risk**

The results showed that the mean ± SD total score for FES-I was 30.2 ± 10.6 and thirty-three participants (65%) had a score of >23, indicating a high level of concern about falling.
Fifty-nine percent, corresponding to 30 participants, expressed some degree of fear of falling when the responses were graded on a four point scale. The correlation between FES-I and the four-grade fear of falling rating was \( \rho = 0.35, p = 0.013 \).

Of the participants, 31 (61%) stated that they were concerned at least to some degree that they would get hurt in the event of a fall, thereby expressing concern about the consequences of falling. Four participants (8%) judged the risk that they would fall within the next six months to be high.

Mobility, morale and concern about the consequences of falling (value 4: very concerned) were variables independently associated with FES-I. The model explained 39% of the variance, \( p<0.001 \) (Table 5).

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Coefficient (95% CI)</th>
<th>Standardized coefficient</th>
<th>P-value</th>
<th>Variance inflation factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>43.6 (34.5 to 52.7)</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>SPPB</td>
<td>-1.1 (-1.9 to -0.2)</td>
<td>-0.30</td>
<td>0.012</td>
<td>1.08</td>
</tr>
<tr>
<td>PGCMS</td>
<td>-0.8 (-1.5 to -0.2)</td>
<td>-0.28</td>
<td>0.017</td>
<td>1.04</td>
</tr>
<tr>
<td>Concern about the consequences of falling, value 4 (reference value 1)</td>
<td>12.9 (4.6 to 21.1)</td>
<td>0.37</td>
<td>0.003</td>
<td>1.12</td>
</tr>
</tbody>
</table>

Dependent variable: FES-I
Variables not included: age, sex, MMSE, self-rated fall risk, falls in the previous 6 months and concern about the consequences of falling, values 2 and 3.

**Activity curtailment**

Figure 2 shows that median values for fall-related concern regarding the separate FES-I items followed two different profiles, depending on whether the activity related to the item was performed independently or not.
When looking at the profile for independent performance, there were items, such as “taking a bath/shower”, “going to the shop”, “walking on slippery and uneven surfaces” and “walking up or down a slope”, which were related to median values indicating “somewhat concerned”. Regarding non-independent activity performance, six items: “walking in the neighborhood”, “going up and down the stairs”, “reaching above head or down to the ground”, “walking on slippery” and “uneven surfaces” and “walking up or down slopes” were connected to median values indicating being at least “fairly concerned”. Only two activities, “visiting friend/relatives” and “going out to a social event/to social events”, resulted in a median value indicating no concern.

Twenty-nine (57 %) participants reported at least one of the assessed activities to be “performed with assistance” because of fear of falling and two reported six activities to be” performed with assistance “. Morale and mobility were independently related to the

![Figure 2](image-url). Profiles of median values for separate FES-I items, depending on whether the activity related to the item was performed independently (diamonds and dashed line) or not (squares and solid line).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Independent/Not independent</th>
<th>Not at all concerned</th>
<th>Somewhat concerned</th>
<th>Fairly concerned</th>
<th>Very concerned</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cleaning the house</td>
<td>24/3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Getting dressed/undressed</td>
<td>42/9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Preparing meals</td>
<td>38/13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Taking bath/shower</td>
<td>29/23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Going to the shop</td>
<td>21/60</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Getting in/out of shower</td>
<td>48/3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Going up/down stairs</td>
<td>31/20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Walking in neighborhood</td>
<td>30/21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Reaching above head/to ground</td>
<td>35/16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Walking on slippery surface</td>
<td>20/31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Visiting friend/relative</td>
<td>27/24</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Walking in crowds</td>
<td>29/22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Walking on uneven surface</td>
<td>24/27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Walking up/down slope</td>
<td>24/27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Going out to social event</td>
<td>30/21</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

38
numbers of activities “performed with assistance” because of fear of falling. The multiple regression models explained 22% of the variance. The standardized coefficients varied between -0.27 and -0.41, the highest absolute value for PGCMS.

Thirteen (26%) participants stated that they “avoided” at least one activity because of fear of falling and one participant “avoided” six activities for this reason. FES-I and PGCMS were independently associated with the number of activities “avoided” because of fear of falling. The multiple regression models explained 24% of the variance. The standardized coefficients were 0.31 and -0.28, the highest absolute value for FES-I.

**Fall detection and expectations of an automatic fall alarm system**

The specificity of the fall detection device, determined from ADL samples, including both middle-aged and older persons in the test, was 100%, indicating no false alarms. The sensitivity using the most reliable fall detection algorithm was 97.5% where the intentional falls were concerned. All forward falls, lateral falls and falling out of bed were detected, while a few backwards falls remained undetected.

The responses to the questions regarding the expectations from an automatic fall alarm system indicated that 74% agreed that it would increase their security, 66% that it would decrease their fear of falling, and 57% that it would increase their freedom of movement, while a total of 28% feared it could affect their privacy.
DISCUSSION

Fall incidence and seasonal variation

Previously, the scarce studies on the occurrence of falls among old home-help recipients have retrospectively described the percentage of people who have suffered falls (28, 29), and therefore the incidence has not previously been described in this population.

The overall fall incidence rate found in this study resembled that previously found in studies of community living older people (22, 24), but we also found that the incidence was strongly correlated to the type and amount of services provided. For people receiving services providing help with P-ADL, the incidence seems to be almost three times higher than among those who do not require help with such activities, coming close to figures reported in residential care populations (21). It seems likely that this connection to the amount of services could be explained by the fact that provision of a greater amount of home-help services is associated with greater impairments among the recipients (10), which, in turn, is associated with an increased fall risk.

Interestingly, the results revealed a seasonal variation in the incidence of falling. However, the fact that almost all falls (97 %) took place indoors excludes a direct comparison with the higher fall incidence at low temperatures reported by Luukinen et al (42) and Campbell et al (43). On the other hand, an interesting connection to the amount of daylight emerged, explaining 61 % of the variance in the monthly incidence of falling. The amount of daylight has rarely been put forward as a factor explaining seasonal variation in the incidence of falls and fractures, but, as suggested by Douglas et al (39), it might increase the understanding of the observed increase in hip fracture incidence during winter months, possibly through its effects on the circadian rhythm, and on vitamin D synthesis. Päkkönen (44) found the level of the hormone thyroid and serum melatonin closely linked to the circadian rhythm, among people taking part in Antarctic expeditions, was significantly correlated with the amount of daylight. Among outdoor-workers, living in a sub-arctic region, the highest serum thyroid level was found in December (45). Further, in a study among very old people in northern Sweden, a thyroid disorder was found to be an independent risk factor for falling (7). It might be that, the fact that our study was
conducted at very high latitude, with extreme seasonal variance in the amount of daylight through the year, contributed to a greater possibility to detect an association to the fall incidence.

**Perceived fall risk**

The perceived fall risk was prominent among the home-help recipients (*Study III*). Approximately two thirds of the participants expressed concern about falling or feared falling over. It is somewhat difficult to compare this prevalence with the results of other studies owing to different sample selections, and methodological approaches being used. However, in this study the prevalence of fear of falling was similar to that reported in a previous study among older people living in senior housing (61). The correlation between fall concern and fear of falling was moderate. This indicates that these constructs, although related to some degree, are at least partially separate from one another.

The total mean score of the FES-I was high (30.2 ± 10.6), and the multiple regression modelling revealed three factors explaining the variance. The strongest explanatory factor was concern about the consequences of falling. It is suggested that catastrophic thoughts and beliefs of the possible devastating consequences a fall might lead to, may be potentially important antecedent of fall related concern (87). Beliefs that a person holds regarding falls such as loss of independence, social embarrassment, and damage to identity (88), including experiences from previous falls (87) might impact the extent to which fall risk is interpreted catastrophic.

Mobility was a strong factor independently associated with concern about falling. Several previous publications have reported that mobility limitations and related impairments are associated with the perceived fall risk (62, 63, 65). This may reflect that part of the risk perception process depends on the judgment of one’s own physical capability (117). Maki et al (118) suggested that fearful individuals have a true deteriorated postural control, and might be aware of this deterioration and this resulted in fear of falling.

The third factor explaining the variance in FES-I was morale. To the best of our knowledge, this association has not been described before. On the other hand, studying
factors of a similar kind, Delbaere (81) found that a positive outlook on life, emotional stability, and low reactivity to stress were linked to a low level of concern about falling.

**Fear-related activity curtailment**

Among the recipients of home-help services, curtailing the performance of independent activity seems to be associated with activity-specific fall-related concern (*Study IV*). This appears to be most strongly expressed for the activities that put the most demand on motor control systems, such as, taking a bath or a shower, walking on a slippery surface or walking on an uneven surface. Similar results have also been reported in previous studies (72, 75, 77).

In contrast with results reported previously, social activities (88), like visiting friends, and going to social events did not seem to give rise to a particular amount of fear. A possible explanation for our finding might be that, in these situations, the respondents would not be alone, but instead, would have support, and it could be that they rely on others for their safety, and for receiving help in the event that they were to fall.

Among the home-help recipients, the median values for the items of the FES-I were almost consistently higher for those reporting that they did not perform the activities independently than for those who did. A detrimental consequence of being concerned about the possibility of falling is the resultant curtailment of activity, leading to inactivity (119), and an increased fall risk (76). More than half of the participants relied on assistance for at least one activity because of a fear of falling, and about one in four avoided at least one activity for the same reason. Several of the participants had curtailed more than one activity. This fact is of importance, since curtailing more than three activities have been found to be connected with a decline in ADL activities and a decrease in lower extremity function (75).

Mobility and morale were significantly associated with the number of activities performed with assistance, because of a fear of falling. Interestingly, only the psychological factors, morale and overall concern of falling, were related to the number of activities avoided. The separation of the activity curtailment into dependence on assistance or ac-
Activity avoidance might have helped to reveal different patterns of variables related to this curtailment, and would be something to consider in future research. Morale seemed to be linked both with a fear-induced dependence on assistance, and avoidance of activities. It seems reasonable that this construct, entailing age-related self-esteem and expectations for the future (82), would have an impact on the psychological processes underlying the perception of the risk of falling, and its consequences for activity performance.

The other psychological factor connected to the degree of activity curtailment was the overall concern about falling (sum score of FES-I). In our analysis, this association was only found regarding activity avoidance, and not assistance dependency. On the other hand, mobility limitations, previously reported to be strongly associated to activity restrictions (64, 66), were only associated with assistance dependency and not activity avoidance in our investigation/in our research. This indicates that different factors mediating concern about falling might have a different impact on the activity-related consequences, such as activity curtailment.

Fall detection and the expectations of an automatic fall alarm

The fall detection device had a capacity to discriminate various types of falls from activities of daily living with a sensitivity of 97.5% and a specificity of 100%. Previously, waist-worn fall detection devices have been reported to have a fall detection sensitivity of 70 – 96% and a specificity of 84-100% (94, 120-122). This indicates that our concept seems to be an effective method for automatic fall detection. The best sensitivity was achieved by using simple algorithms, based on impact and end posture after the fall. Recently, similar results regarding the sensitivity and specificity of a device using a simple algorithm system based on impact, velocity and posture have been reported (122). Differences in the sensitivity of the algorithm were observed in our study, indicating different mechanisms for different falls. All forward and 90% of the backward falls exhibited three phases: start, impact, and horizontal end posture, although these criteria were not fulfilled for rolling out of bed, and lateral falls exhibited a high falling velocity in conjunction with the three phases of falling.
The positive perception of the potential of an automatic fall alarm intended to increase the security of frail elderly people, and thereby to enhance their freedom of movement. As one would anticipate, when questioned about their requirements of such a device, it seems to be important for most home care recipients that falls will be detected by staff rapidly, presumably to ensure that they receive help without delay when it is needed. This is in line with the findings reported in a recent study regarding mobile alarm systems (93). Most falls occur when the person is alone and a great proportion of those who fall are unable to get back up again, especially those of an advanced age (52). However, it should be noted that several respondents expressed concern about a possible violation of their privacy, pointing out that individual needs and circumstances must be taken into account when use of such devices is considered. In an automatic fall alarm intervention study, it was found that most participants had positive experiences of using security alarm (123). No effects were found on fall-efficacy, in comparison to a control group, however, this analysis was obviously under-powered, and possibly obscured by study effects on the control group.

Methodological considerations

Although the number of home-help recipients was somewhat lower in the municipality studied compared with national figures (13) the sample included in Study I can be seen to be approximately representative of the recipients of home-help services in Sweden. However, the difference might indicate some risk for an over-estimation of the fall incidence rate.

In Study II the sampling was purposive, and its external validity should be judged from a contextual perspective rather than statistical population representativity. Both samples consisted of about 20 individuals which is large enough to allow some variance in the sampling. The older sample was recruited from residential care facilities, and they presented physical impairments. From an ethical point of view, it was seen as impossible to study intentional falls among old people. Based on studies of motor control (124, 125),
middle-aged people could be expected to mimic the fall events of older people more adequately than young subjects would.

The sample of Studies III-IV was large enough, according to the statistical power demands required in Study III, and seemed to be representative of the population under investigation, regarding age, sex, and the amount of services provided. Still, the response rate was quite low, which may have affected the results, and drawing from some of the analyses in Study IV, a larger sample would probably have been preferable in these specific analyses. In studies depending on fall reports, there is always a risk of under-reporting. Therefore, in Study I, staff members were carefully instructed and motivated to fill in the report forms and reminded about this at regular staff meetings throughout the study. However, there is still a risk of a relative under-reporting of falls among home-help recipients seldom visited by the home-help staff that cannot be neglected. Injury and fracture frequencies in Study I may be seen as indicators that under-reporting is not much higher than in similar studies, since in cases of low reporting rates, injurious falls should be relatively over-reported.

The validity of letting deliberate falls represent real-life falls (Study II) is unknown. Being prepared for a fall probably would affect its character (126). This means that the virtues of the fall detection system should be further studied in real life contexts.

In Studies III-IV, well-known, reliable and valid assessment scales were used, and the assessors involved were experienced. The questions regarding concern about the consequences of falling, self-rated risk, and activity curtailment were constructed using questions posed in previous similar studies as a base (72, 114, 127), however they were not tested for test-retest reliability. One must also bear in mind that Studies III-IV was cross-sectional, and therefore causal relations between variables cannot be established.

Fall incidence rate ratios were calculated using negative binomial regression (Study I). This method was used since it takes into account the dependence of events reported by the same individual (115). The association between seasonal variations in fall incidence and the amount of daylight over the year was analysed using one month as the time unit. A larger sample would probably have allowed for a greater resolution.

As purposive sampling was conducted in Study II, no inferential statistics were applied. The multiple regression models in Studies III-IV were based on pre-selected independent
variables, and default software settings were strictly used in the stepwise procedures. Multicollinearity seemed to have been avoided since the largest estimate of the variance inflation factor (VIF) found for a separate independent variable was 1.432.

**Concluding discussion**

The incidence of falling, perceived fall risk and associated activity curtailment have not been assessed before for the specific population under study. From this study it can be concluded that these phenomena are quite prevalent, a fact which probably entails consequences for health and wellbeing among the individuals concerned.

Introducing risk-theory motivated factors such as self-rated risk and consequence concern as well as the introduction of the factor morale in the study of the factors related to the perceived fall risk seemed to be fruitful. The results indicate that concern about the consequences of falling is to be considered a mediating factor for concern about falling. Apparently, the variance in the cognitive factor self-rated risk might have been too low to allow for inclusion in the model, however it is interesting that many old home help recipients seem concerned about falls but few rate their risk for falls to be high. As a suggestion, we might consider the impact of morale on the perceived fall risk and also on fear-related activity curtailment, as a result of the fact that morale is known to be closely associated with self-efficacy.

The separation of activity curtailment into dependence on assistance and avoidance seems to have contributed to a more nuanced picture of the problem. It would appear that factors associated with the two aspects differ in some ways. The findings of this study are consistent with the results of Mendez de Leone et al (128), who described that, given the existence of functional impairments, dependence on assistance is related to self-efficacy. In our study, this assistance dependence was related to mobility, which is linked to functional impairments, and to morale, which can be understood to be strongly linked to self-efficacy. Further, having both low morale scores and high scores for global fall-related concern seem to significantly increase the probability of an activity being completely
avoided. For future research, longitudinal studies of the progression of activity curtailment and well-being related to the perceived fall risk are recommended.

Automatic fall alarms appear to have potential as measures for reducing fall-related feelings of insecurity among individuals in the population, but they should be further tried in real-life contexts. Concerns regarding violation of privacy should be taken into account in this respect. Other interventions more directly aimed at tackling the causes of fear-related concern should also be considered. There is strong evidence that physical exercise and fall-related multifactor programmes reduce the fall risk (89), improve mobility (129), and reduce the fear of falling (90). Recent studies also point to the possibility of reducing the perceived fall risk using cognitive behavioural interventions (92).

This study is, as far as we are aware, the first to present an association between the incidence of falling and seasonal variation in the amount of daylight. This interesting observation, which contradicts previous findings, might be explained by the study having been performed at very high latitude (65° 50’ N). This should be verified in future studies, and if it proves to be valid, reasons for this possible daylight dependence should be explored.
Conclusions and implications

This study reveals that:

- Falls and perceived fall risk seem to be common phenomena among older recipients of home-help services.
- Mobility, concern about the consequences of falling and morale appear to be connected both with fall-related concern and fall-related activity curtailment.
- A fall detector system shows promising potential for use among the recipients of home-help services.
- The correlation between fall incidence and the amount of daylight should be further explored.

This implies that, from a general perspective, falls and fall-related concern among older home-help recipients should be acknowledged by care professionals, and should be accounted for when planning the provision of services. The Swedish Social Service Act (8) states that “The social welfare committee shall endeavour to ensure that older persons are enabled to live independently and securely...” The findings of this study indicate that services provided to people with self-care limitations might not be quite adequate from the perspective of safety and the promotion of a sense of security. Multifactor intervention programmes, possibly including cognitive behavioural actions, should be launched. Physiotherapists in community health care should engage in intervention programmes, and specifically contribute by providing opportunities for specific and intense exercise (130). The evidence advocates multicomponent exercise, which could be performed in supervised groups, such as Tai Chi sessions, or as individually prescribed home exercise programmes (89). In addition, attempts to adopt behavioural approaches might be considered in specific physiotherapy interventions.
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Incidence and seasonality of falls amongst old people receiving home help services in a municipality in northern Sweden

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ABSTRACT

Objectives. Falls among old people is a well-documented phenomenon; however, falls among people living in the community and receiving home help services have been under-researched. The aim of this study was to investigate the incidence, including possible seasonal variation, circumstances and injuries related to falls among community living home help receivers, and to investigate whether fall incidence is associated with the type and amount of home help services received.

Study design. Prospective cohort study.

Methods. All 614 persons aged 65 and over who were living in a particular northern Swedish community and receiving municipality home help were included. Data on age, sex and home help service use were collected from home help service records, and falls were reported by staff on report forms specifically designed for the study.

Results. A total number of 264 falls were recorded among 122 participants. The overall fall incidence was 626 per 1,000 PY, and incidence rate ratios were significantly correlated to the total amount of services used (p<0.001), as well as to the degree of help for I-ADL needs (p<0.001), P-ADL needs (p<0.001) and escort service (p=0.007). The proportion of falls reported as resulting in injury was 33%. The monthly fall incidence was significantly associated to daylight photoperiod, however it was not associated to temperature.

Conclusions. Fall incidence among home help receivers aged 65 and over seems correlated to the amount of services they receive. This is probably explained by the fact that impairments connected to ADL limitations and home help needs also are connected to an increased risk of falls. This implies that fall prevention should be considered when planning home help care for old people with ADL limitations. Further research on the connection between daylight photoperiod and fall incidence in populations at different latitudes is needed.

Keywords: accidental falls, aged, aged 80 and over, cohort studies, home help services, incidence, seasons
INTRODUCTION

Falls constitute a major age-related public health problem and represent a well-documented phenomenon among old people living in the community (1–4). They have also been studied among old people in various forms of residential care (3,5). However, falls among old people living in the community and receiving home help services have been under-researched. In studies of community-living old people, home help receivers have been included (2,3), but not specifically reported. To our knowledge there are only 2 studies that have focused on similar, though not identical, populations (6,7). Both these studies were retrospective with short timespans.

The fall incidence rate in community-living old people has in different studies been variably estimated at 517 per 1,000 person-years (PY) (3) and 683 per 1,000 PY (2). Amongst old people in residential care, corresponding figures have been estimated at 1,581 per 1,000 PY (3) and 2,236 per 1,000 PY (5). Intrinsic risk factors have been extensively studied and include advanced age; female sex; cognition, vision, sensory function and muscle strength impairments; gait, balance, mobility and ADL limitations; fear of falling and attention deficits; and medical diagnoses such as stroke, Parkinson’s disease and a number of chronic diseases (4). Environmental factors such as slippery surfaces, obstacles causing stumbling, low light and so on seem more weakly associated to falls than these intrinsic factors. It is likely that the occurrence of falls will be determined by the interaction between the old person’s functional abilities and the environment, rather than the environmental risk factors in and of themselves (4).

A factor of special interest regarding circumpolar populations may be the potential association between seasonal conditions and the occurrence of falls, which has been studied to a limited extent. Seasonal variance in hip fracture incidence, with higher incidence connected to winter conditions, has been reported in several studies (8–11). Regarding fall incidence, no consistent pattern of seasonal variation was found among old people in residential care in Sweden (3), nor regarding injurious falls among community-living old people in Finland (12). On the other hand, among community-living people aged 70 and older, Luukinen et al. (13) demonstrated a higher incidence of outdoor falls during periods of extreme cold, and Campbell et al. (14) showed an association between low temperatures and fall incidence among women.

Falls have a significant impact on health and life quality in old age, as well as on the health care system. They are the leading cause of injury-related hospitalization in persons aged 65 and over (15), and the direct societal costs of falls in Sweden (population 9 million) were estimated at 5 billion SEK in 2003 (16). Besides injurious consequences, falls can also result in a fear of falling, which, in turn, is associated with a restriction in activity and loss of independence (17–19). The ratio of falls resulting in injury is typically reported to be about half of the falls in community populations (2,20) and about one-third in residential care population (5). About 1 fall in 10 results in fractures or other more significant injuries (2,5,20).

In Sweden, 140,300 people aged 65 or older received home help services in their own homes during 2006 (21). This represents 9% of the population of this age group. Home help services are allocated according to individual needs and the amount of services required is strongly correlated to ADL dependency as well as cognitive impairments and advanced age (22). The overall number of old people receiving elderly care has been basically stable since the year 2001. Simultaneously, however, the number of old people living in resi-
Falls in old people receiving home help

dential care has decreased and the number of old people receiving home help has increased (21). This indicates that many old individuals receiving home help services constitute a transitional group between independent, community-living old people and people in residential care, and that there is a trend towards a greater resemblance between home help receivers and the latter group.

Thus, this study is a first attempt to look specifically at the occurrence of falls in an important population of old people which may form a transitional group between community-living old people and institutional care residents. The aim was to investigate incidence (including possible seasonal variation), circumstances and injuries related to falls among elderly community dwellers receiving home help services, and to investigate whether fall incidence is associated to the type and amount of home help services received.

MATERIAL AND METHODS

This 1-year prospective cohort study was conducted in a municipality in the north of Sweden, located at latitude 65.50° N. The number of inhabitants was 28,002 and 19% were aged 65 and older. In Sweden, almost 90% of home help services are provided by municipal authorities and 10% by other caregivers. In the municipality that was the focus of this study, 100% of home help services were provided by the municipal authority.

The criteria for inclusion involved being age 65 or older and having received regular municipality home help services for long or short intervals during 1 particular year. Participants matching the inclusion criteria were identified through monthly reviews of the home help service records, from which data were collected concerning each participant’s age, sex and the type and amount of home help service they used.

Types of home help services were categorized as follows: instrumental ADL (support and help with instrumental activities of daily living, e.g., cooking and shopping); personal ADL (support and help with personal activities of daily living, e.g., dressing and using the toilet); security/social support (regular visits by home care staff in order to provide a feeling of security); relief service in the home (home care staff provide a caregiver with an opportunity to pursue activities of his or her own choice or simply to have a rest); escort service (home care staff accompanies the elderly person to an activity outside the elderly person’s home).

All 614 individuals matching the inclusion criteria were included and registered in the study using a code number. Their mean age (±SD) was 81.8±6.8 years, and 410 (67%) were women. The distribution of home help services is presented in Table I. Median time in the study (exposure time) was 304 days (Q1, Q3: 132, 365) and 270 participants were followed for 1 full year. The number of participants included at start of the study was 410 and 204 more were added during the study period as they became regular home help receivers. The number of participants that were followed until the end of the study was 395, while 53 died, 65 moved to residential care facilities, and 101 ceased being home help service users before the end date of the study.

Falls occurring among the participants during their involvement in the study were documented following a methodology used previously in residential care (5): falls were defined as events in which the person, unintentionally and regardless of cause, came to rest on the floor or another lower level. The home help service staff were instructed to report every event that came to their attention and met with this definition on a specifically designed fall report form. It included person identification...
Falls in old people receiving home help data, date, time and location of the fall, as well as the ongoing activity. Consequences – such as injuries and anxiety – and measures taken after the fall were also registered on the report. As it is expected that most falls will not be witnessed by staff (23), they were instructed to gather as much information as possible from the individual concerned, or other persons, whenever a fall came to their attention. Reports were sent to the researchers on a monthly basis.

The study was approved by the authority of the involved municipality and the Regional Ethical Vetting Board in Umeå (Dnr 05-150M). A project management group of researchers, home help service officials and staff representatives prepared the practical routines and monitored the fall data and participant data collection throughout the study. Staff members were informed of the study’s aims and instructed regarding the management of the fall reports during a series of meetings prior to the study’s start. At staff meetings throughout the study period, they were reminded and encouraged to keep up with reporting routines.

Descriptive data are presented as means, medians, numbers, percentages and incidence rates. For the calculation of incidence rates, the number of incidents occurring among individuals in the total sample or in subgroups was divided by the individuals’ aggregated exposure time during the corresponding time period.

In order to assess seasonal variation in fall incidence, monthly fall incidence rates were described and associated by linear regression with the mean daylight photoperiod (number of daylight hours for the 15th day of each month) or with mean temperatures, collected from the Swedish Meteorological and Hydrological Institute (SMHI).

For comparison of fall incidence rates between subgroups, incidence rate ratios (IRR) with a 95% confidence interval were calculated using a negative binomial regression (nbreg) (Stata software, version 10.0; StataCorp, College Station, Texas). This method was used because it takes into account the dependence of events by the same individual and it is recommended for use in the evaluation of fall prevention (24).

**RESULTS**

During 1 year, 264 falls occurred among 122 of the participants (20%). Among the fallers, 74 (61%) had 1 fall, and 48 (39%) had more than 1 fall, ranging up to 11. The fall incidence (and 95% confidence interval) rate was 626 (479–773) per 1,000 PY. The fall incidence rate ratio was not related to sex (IRR for women compared to men: 0.92; 95% CI: 0.57–1.51; p=0.752), but the incidence was positively associated with advancing age (IRR: 1.06; 95% CI: 1.02–1.05; p<0.001).

The monthly fall incidence seemed to roughly follow a sinusoidal curve (Fig. 1), however it was inverted to the daylight photoperiod and temperature variation during the year. As can be seen

<table>
<thead>
<tr>
<th>Table I. Distribution of home help services, n=614.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of service</strong></td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>Total service amount</td>
</tr>
<tr>
<td>Instrumental ADL</td>
</tr>
<tr>
<td>Personal ADL</td>
</tr>
<tr>
<td>Security/social support</td>
</tr>
<tr>
<td>Relief service in the home</td>
</tr>
<tr>
<td>Escort service</td>
</tr>
</tbody>
</table>
from Table II, the variation in fall incidence had a
significant correlation to the photoperiod ($r=-0.78$;
$r^2=0.61; p=0.003$) but not to the mean temperature
($r=-0.51; r^2=0.26; p=0.090$).

Falls were rather equally distributed during
day and night, with the exception of a lower
frequency during midday between 10.00 and
14.00 (Table III). The number of falls during
night hours (22.00–07.00) corresponded closely
to an overall mean frequency.

Figure 1. Monthly variation in fall incidence rate.

Table II. Monthly fall incidence rate and its correlation to photoperiod and mean temperature.

<table>
<thead>
<tr>
<th>Month</th>
<th>Fall incidence rate per 1,000 PY</th>
<th>Mean photoperiod (hours)*</th>
<th>Mean temperature (centigrades)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>951</td>
<td>04:46</td>
<td>-5.9</td>
</tr>
<tr>
<td>February</td>
<td>516</td>
<td>08:22</td>
<td>-9.8</td>
</tr>
<tr>
<td>March</td>
<td>468</td>
<td>11:39</td>
<td>-9.1</td>
</tr>
<tr>
<td>April</td>
<td>426</td>
<td>15:17</td>
<td>0.8</td>
</tr>
<tr>
<td>May</td>
<td>300</td>
<td>18:58</td>
<td>7.9</td>
</tr>
<tr>
<td>June</td>
<td>456</td>
<td>22:50</td>
<td>13.1</td>
</tr>
<tr>
<td>July</td>
<td>451</td>
<td>20:41</td>
<td>16.2</td>
</tr>
<tr>
<td>August</td>
<td>313</td>
<td>16:47</td>
<td>17.6</td>
</tr>
<tr>
<td>September</td>
<td>520</td>
<td>13:09</td>
<td>10.9</td>
</tr>
<tr>
<td>October</td>
<td>944</td>
<td>09:41</td>
<td>4.8</td>
</tr>
<tr>
<td>November</td>
<td>756</td>
<td>06:03</td>
<td>0.4</td>
</tr>
<tr>
<td>December</td>
<td>1,388</td>
<td>03:17</td>
<td>-7.8</td>
</tr>
</tbody>
</table>

Correlation to monthly fall incidence:

$r$  
$r^2$  
$p$  

* Number of daylight hours calculated for the 15th day of each month.

Table III. Time for occurrence of falls, n=264.

<table>
<thead>
<tr>
<th>Time intervals</th>
<th>Frequency</th>
<th>Percent</th>
<th>Standardized percent*</th>
</tr>
</thead>
<tbody>
<tr>
<td>07.00–10.00</td>
<td>35</td>
<td>14%</td>
<td>23%</td>
</tr>
<tr>
<td>10.00–14.00</td>
<td>28</td>
<td>12%</td>
<td>14%</td>
</tr>
<tr>
<td>14.00–17.00</td>
<td>29</td>
<td>12%</td>
<td>19%</td>
</tr>
<tr>
<td>17.00–22.00</td>
<td>61</td>
<td>25%</td>
<td>24%</td>
</tr>
<tr>
<td>22.00–07.00</td>
<td>90</td>
<td>37%</td>
<td>20%</td>
</tr>
</tbody>
</table>

* Standardized percent adjusted for different lengths of the intervals. Data missing for 21 falls.
Falls in old people receiving home help

Of the 259 falls for which location was described, 247 (97%) occurred indoors. The most common locations for indoor falls were the bedroom (34%), the kitchen (24%) and the bathroom (21%). The most common activities connected to these falls were walking indoors and standing up/sitting down (Table IV).

Injuries were reported in 82 of 249 falls (33%, data missing for 15 cases), which corresponds to a fall injury incidence rate of 194 per 1,000 PY. Fractures were reported in 11 of the falls (4%), corresponding to a rate of 26 per 1,000 PY.

In 59 falls (22%), staff reported that the home care user experienced fear or anxiety as a consequence of the fall. Hospital care was the consequence of 29 falls (11%). Other reported consequences were consultations with a general practitioner (8 cases; 3%), consultation with a registered nurse (22 cases; 8%) and increased home care levels (9 cases; 3%). In 170 cases (64%), no specific consequence was reported.

As can be seen in Table V, a higher total amount of home help services, as well as higher specific amounts of instrumental ADL, personal ADL and escort services, was significantly associated with higher incidence of falls. Point IRR estimates indicated a 7% increase in the risk of falls per each increased weekly hour of home help services. For instrumental and personal ADL help, which accounted for 80% of the total amount of service provided, the corresponding figures were 19% and 9%, respectively.

We tried to adjust the incidence rate ratio calculations for age. This showed only marginal effects on IRRs and confidence intervals and no changes regarding significant associations were shown. Thus, results are presented without age adjustments.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking indoors</td>
<td>95</td>
<td>36 %</td>
</tr>
<tr>
<td>Standing up / sitting down</td>
<td>47</td>
<td>18 %</td>
</tr>
<tr>
<td>Lying in bed / sitting in chair</td>
<td>23</td>
<td>9 %</td>
</tr>
<tr>
<td>Transfer between chair and bed</td>
<td>11</td>
<td>4 %</td>
</tr>
<tr>
<td>Standing still</td>
<td>8</td>
<td>3 %</td>
</tr>
<tr>
<td>Walking outdoors</td>
<td>7</td>
<td>3 %</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>6 %</td>
</tr>
<tr>
<td>Unknown</td>
<td>47</td>
<td>17 %</td>
</tr>
<tr>
<td>Missing data</td>
<td>10</td>
<td>4 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Home help service (hours/week)</th>
<th>IRR*</th>
<th>95% confidence interval</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total service amount</td>
<td>1.07</td>
<td>1.04–1.10</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Instrumental ADL help</td>
<td>1.19</td>
<td>1.11–1.28</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Personal ADL help</td>
<td>1.09</td>
<td>1.04–1.15</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Security/social support</td>
<td>1.08</td>
<td>0.96–1.22</td>
<td>0.213</td>
</tr>
<tr>
<td>Relief service in the home</td>
<td>0.75</td>
<td>0.49–1.14</td>
<td>0.178</td>
</tr>
<tr>
<td>Escort service</td>
<td>1.97</td>
<td>1.20–3.23</td>
<td>0.007</td>
</tr>
</tbody>
</table>

* Negative binominal regression. The total amount and the amounts of each specific type of service are each independent variables in separate bivariate analyses with falls as the dependent variable.
DISCUSSION

This study presented an overall fall incidence rate among old people receiving home help services which was comparable to that found among community-living old people (2,3). However, the incidence rate was strongly correlated to the amount of services received, and specifically to services related to self-care limitations. This study also presented a consistent pattern of seasonal variation in fall incidence, correlated to the daylight photoperiod.

To our knowledge this is the first study to present fall incidence rate among old people living in their own homes and receiving home help services. Fletcher et al. (6), in a retrospective study of a cohort of home care service receivers, reported that 27% fell over a 90-day period. Lewis et al. (7), in a retrospective case-control study, reported that 6% of individuals receiving home health services during a single year suffered falls. The services in these studies included health care provided in the home by professionals, rather than help with carrying out activities in daily life in the home.

The circumstances surrounding the falls reported in this study resemble those found among old people in residential care (5). This applies to the facts that almost all falls occurred indoors, that the most frequent locations for these falls were the bedroom, kitchen and bathroom, that walking and rising/sitting down were the most common activities connected to falls and that falls occurring during night-time were quite common (considering the fact that people could be expected to be at rest during these hours). Among community-living old people, on the other hand, almost half of the falls seemed to take place outdoors (16) and the percentage of night-time falls has been variably estimated to count for 2% (25) and 4% (26) of cases.

The overall incidence rates of falls, injuries and fractures among old people receiving home help services did not seem to be much higher than those among community-living old people in general (2,3,20,27), but there was a strong and important correlation between the amount of service provided and the fall incidence. Our findings indicate that people receiving greater amounts of home care services resemble residential care populations more than community populations in regards to both fall incidence and fall circumstances. Further, we interpreted the connection between falls and the amount of services provided to be a consequence of the fact that a greater amount of home care services is associated with greater impairment (22) which in turn is associated with a greater fall risk. Therefore, fall prevention measures should be a serious concern when planning home help services, especially for people with greater needs because of ADL limitations.

The seasonal fall incidence variation presented in this paper might add interesting information to previous findings in the literature (8–14). The fact that almost all falls (97%) took place indoors excludes a direct comparison with the higher fall incidence at low temperatures that was reported by Luukinen et al. (13) and Campell et al. (14). On the other hand, an interesting connection to the daylight photoperiod emerged, explaining 58% of the variance in monthly fall incidence. The photoperiod has rarely been used as a factor to explain seasonal variation in falls and fracture incidence, but as suggested by Douglas et al. (10), doing so might help to explain the observed increase in hip fracture incidence during winter months, possibly through the photoperiod’s effects on...
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circadian rhythms and D-vitamin synthesis. The fact that our study was conducted at very high latitude, with extreme seasonal variance in the daylight photoperiod, might have contributed to our ability to detect such an association. More research is needed, however, regarding both the seasonal variation of falls at different latitudes and the effects of the photoperiod on the risk of falls. In line with the discussion of Luukinen et al. (13) – which suggests that heating and insulation against the cold creates comfortable indoor temperatures regardless of very low outdoor temperatures and thereby possibly reduces the effects of low temperatures on fall incidence – it would be interesting to study how ordinary indoor illumination may or may not reduce the effects of the lack of daylight during the long, dark winter months at high altitudes.

We postulate that the municipality used in this study can be seen as approximately representative for home help services across Sweden, although there is some variance among municipalities regarding home help service provision. Compared to national figures (21), the total number of home help receivers is somewhat lower in the municipality studied here; however, the number of people receiving greater amounts of services (50 hours per month and more) is somewhat higher in this municipality. This may imply a slight risk of overestimation of the fall incidence rate.

Unfortunately, for practical and financial reasons, it was not possible for us to collect data on previous falls, health conditions, cognitive function, medication or gait and mobility activity limitations among the participants. This is an external validity limitation and it also means that we were not able to study the direct connections between participant characteristics and fall incidence. Nor could we compare fall incidence rates between populations of community-living old people who were receiving and not receiving home help services.

In studies depending on fall reports, there is always a risk of under-reporting. Falls might occur without coming to the attention to of the staff, and staff may neglect to report known fall cases. Therefore, we and the district managers of the home help organization were careful to instruct and motivate staff members to fill in the report forms and to remind them about this at regular staff meetings throughout the study. However, there is still a risk of a relative under-reporting of falls among people seldom visited by the home help staff that cannot be ignored. The method of collecting fall report forms that have been filled in by staff implies a loss of detail and precision in injury recording, however, we expect that fractures and other serious injuries were not under-reported to any great degree in this study because of regular contact routines between the home help services, health care centres and hospital clinics. Injury and fracture frequencies in this study may be seen as indicators that under-reporting is not much higher than in similar studies, since in cases of low report rates, injurious falls should be relatively over-reported.

In conclusion, our study shows that the fall incidence rates among home help receivers aged 65 and older are comparable to those reported among community-living old people. However, the fall incidence rate among home help receivers seemed correlated to the amount and type of services they received, especially services related to ADL limitations. The Swedish Social Service Act (28) states that "the social welfare committee shall endeavour to ensure that older
persons are enabled to live independently and securely..." The findings of this study indicate that services provided to people with self-care limitations might not be quite sufficient from a safety and security perspective. This means that falls are an important issue for home help providers to consider.

We suggest that fall prevention measures should be considered when deciding on which services to provide, and that staff should be suitably trained for delivering services from a fall prevention perspective. This is becoming even more important since there is a growing tendency for home help services to be provided to people with greater and greater impairments and limitations (29). From a more general fall research perspective, the seasonal variation of fall incidence and its possible relation to the daylight photoperiod should be further investigated.

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We have no conflict of interest to give account for.

REFERENCES
Falls in old people receiving home help


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Sensitivity and specificity of fall detection in people aged 40 years and over
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ABSTRACT
About one third of home-dwelling people over 65 years of age fall each year. Falling, and the fear of falling, is one of the major health risks that affects the quality of life among older people, threatening their independent living. In our pilot study, we found that fall detection with a waist-worn triaxial accelerometer is reliable with quite simple detection algorithms. The aim of this study was to validate the data collection of a new fall detector prototype and to define the sensitivity and specificity of different fall detection algorithms with simulated falls from 20 middle-aged (40–65 years old) test subjects. Activities of daily living (ADL) performed by the middle-aged subjects, and also by 21 older people (aged 58–98 years) from a residential care unit, were used as a reference. The results showed that the hardware platform and algorithms used can discriminate various types of falls from ADL with a sensitivity of 97.5% and a specificity of 100%. This suggests that the present concept provides an effective method for automatic fall detection.

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1. Introduction
The population over 65 years of age is growing rapidly in most countries. Several studies indicate that approximately one third of home-dwelling people over 65 years of age fall each year [1,2]. Among those in residential care, about two thirds fall each year [3]. Falls result in major soft tissue injuries, fractures, and deaths.

Falling, and the associated fear of falling, is one of the major health risks that affects the quality of life among older people, threatening their independent living [4]. People living in residential home care or having home-help services most often fall when they are not observed by staff or relatives [5]. There is also a risk of serious under-estimation of the number of falls in the older population. Fall events are often not reported if the faller recovers without serious injuries, but they may still result in undetected injuries, anxiety, distress [6].

Automated fall detectors have been developed to support independent living and safety. These detectors are mostly based on body-attached accelerometers. Most of the reported fall detection applications are prototypes or applications for research purposes [7–12]. Fall detection algorithms detect different phases of a fall event: (1) motion before impact, based on high velocity [9,13]; fast posture change [14], or free fall [8,13]; (2) impact itself, based on high acceleration [7,8,10] or a rapid change in acceleration [12]; and (3) end posture or reduced general activity after the impact [10,13]. Commercial interest in body-attached fall detectors has also been shown [15–17].

In our earlier studies, we found that fall detection with a waist-worn triaxial accelerometer and quite simple algorithms would be sufficient for fall detection [18,19]. In these preliminary studies, the number of test subjects was small, which is typical in studies of this type [7,9–12]. Even if a higher number of test subjects has been used [8], these studies have typically been performed with young people. Here we implemented our hardware setting in a new fall detector prototype. Since intentional falls with older people are ethically questionable, the aim of this study was to validate the data collection of the device and to define the sensitivity and specificity of different fall detection algorithms with simulated falls in 20 middle-aged test subjects. Activities of daily living (ADL) from middle-aged and older people were used as a reference. The secondary aim was to evaluate the effect of restricted data processing capacity on fall detection sensitivity and specificity for further implementation.

2. Materials and methods
2.1. Subjects
The study protocol was approved by the Regional Ethical Review Board in Umeå, Sweden (approval number 05-105M). Participants received oral information about the study and a written informed consent was obtained.

Study groups were from two different populations, the first one being 20 voluntary middle-aged subjects (40–65 years old), recruited from among staff at the Luleå University of Technology, and the second one being 21 voluntary older people (58–98 years old) recruited from those living in or participating in...
residential care facilities (Table 1). The middle-aged test subjects performed both intentional falls and ADL, while the older subjects performed only ADL. Walking speed (Table 1) was calculated based on a 10-m walking test indoors. A history of falls during the previous 6 months was obtained from each test subject (Table 1).

2.2. Falls and ADL

Middle-aged test subjects performed six different falls (syncope, tripping, sitting on empty air, slipping, lateral fall, rolling out of bed) in a laboratory environment. Fall types were selected to fit into the broader categories of typical fall events [20]. Falls were performed from a podium (height 29 cm) or from a bed (height 80 cm) onto a mattress (height 35 cm). Test subjects received short instructions concerning the direction of fall and the activity to be mimicked, and they were asked to remain lying down a few seconds after impact. Each fall type was demonstrated once by a researcher, and performed twice by each test subject. Subjects wore wrist protectors during the test falls. None of them complained of pain or other discomfort related to tests.

Each subject performed a sequential ADL protocol that was later cut into four samples for data analyses: (1) sitting down on a chair and getting up; (2) picking up an object from the floor; (3) lying down on a bed and getting up; and (4) walking, including both level walking and walking up and down the stairs. Four of the older people did not take the stairs due to limitations in their physical performance. ADL was performed in a laboratory (middle-aged people) or residential home facility (older people). Standard height chairs with arms and standard height beds were used. On average, the whole ADL sequence (mean (range)) took 1:46 (1:22–2:15) min and 3:55 (2:04–8:40) min in the groups of middle-aged and older people, respectively. Falls and ADL sequences were documented using a digital video camera.

2.3. Accelerometry and data processing

Acceleration data were measured during falls and ADL using a device (dimensions 109 mm × 69 mm × 24 mm) attached with an elastic belt at the waist in front of the anterior superior iliac spine. The new prototype hardware platform integrated a 3-axis triaxial accelerometer (ADXL330, Analog Devices) with a sampling frequency of 50 Hz. The accelerometer was connected to an 8-bit CMOS microcontroller (PIC18F6627, Microchip) via an operational amplifier (LT1496, Linear Technologies). The hardware platform also included a transceiver (ST3232, ST Microelectronics) enabling RS232 communication.

The application software of the prototype was modelled as reactive objects (Obj) (Fig. 1). After system startup, the getSample method is rescheduled every 20 ms. On every method invocation ADC_Obj returns the acceleration value of each accelerometer axis and the values are sent to computer using printObj. The objects were scheduled by a real-time kernel based on the high-level programming and systems modelling language Timber [21] and they were implemented in the C language by using TinyTim [22]. This implementation strategy was used to meet real-time requirements.

Acceleration data were collected into a portable computer and converted into gravitational units with a custom-made MATLAB (R2006a) program. Each acceleration axis was calibrated statically against gravitation. Fall detection simulation was done in a virtual environment with a custom-made LabVIEW (8.2) program as described previously [18,19]. Acceleration data were median filtered with a window length of three samples, and low-pass or high-pass filtered with a cut-off frequency of 0.25 Hz when needed.

Parameters used for fall detection were similar to those in our previous studies [18,19]. Briefly, the total sum vector $\mathbf{SV}_{TOT}$ and dynamic sum vector $\mathbf{SV}_{D}$ were calculated for impact detection. $\mathbf{SV}_{TOT}$ was also used to analyze the start of the fall with a threshold of 0.6 $g$. Fast acceleration changes were investigated by the sum

Table 1

<table>
<thead>
<tr>
<th>Characteristics of the study subjects.</th>
<th>Middle-aged ($n = 20$)</th>
<th>Elderly ($n = 21$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (male/female, $n$)</td>
<td>0/14</td>
<td>11/10</td>
</tr>
<tr>
<td>Age (mean ± S.D., years)</td>
<td>48.4 ± 6.8</td>
<td>82.8 ± 9.4</td>
</tr>
<tr>
<td>Walking aid used daily/during the ADL test ($n$)</td>
<td>0/0</td>
<td>18/9</td>
</tr>
<tr>
<td>Walking speed ($\text{mean ± S.D., m/s}$)</td>
<td>1.43 ± 0.20</td>
<td>0.75 ± 0.30</td>
</tr>
<tr>
<td>Fall history ($n$)</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

* Average of two repeated measurements.  
+ Subjects with at least one fall during the past 6 months.
vector $SV_{\text{MaxMin}}$, which was calculated using the differences between the maximum and minimum acceleration values in a 0.1 s sliding window for each axis. Vertical acceleration $Z_2$ was calculated as indicated in Eq. (1):

$$Z_2 = SV_{\text{TV}} - SV_{\text{G}}^2,$$

where $SV_{\text{TOT}}$ = total sum vector (g), $SV_{\text{G}}$ = dynamic sum vector (g), and $G$ = gravitational component $= 1$ g.

Velocity $v_0$ was calculated by integrating the area of $SV_{\text{TV}}$ from the pit around the start of the fall until the impact [18]. End posture was detected 2 s after the impact from the low-pass filtered vertical signal.

Fall detection was tested with detection algorithms described earlier [18,19]. Briefly, three different detection algorithms with increasing complexity were investigated, monitoring two or more of the following phases of a fall event: start of the fall, falling velocity, fall impact, and posture after the fall. Algorithm 1 (beginning + posture) detected a fall if an impact was detected and end posture was used for $SV_{\text{TOT}}$, $SV_{\text{V}}$, and $SV_{\text{MaxMin}}$ respectively [18]. Algorithm 2 (start of fall + velocity + impact + posture) additionally required the detection of start of the fall within a time window of 1 s before impact. Algorithm 3 (start of fall + velocity + impact + posture) additionally required that velocity $v_0$ before the impact was above the threshold value of 0.7 ms$^{-1}$ [18,19]. Algorithms 2 and 3 were tested with impact detection using $SV_{\text{TOT}}$ and $Z_2$ parameters.

To estimate the effect of restricted data processing capacity, fall detection algorithm 1, using $SV_{\text{TOT}}$, $SV_{\text{V}}$, and $Z_2$ parameters, was tested with acceleration data downscaled from floating point to 16- or 8-bit integer format with LabVIEW. For 16-bit simulation, acceleration data were scaled by a factor of 10 before data format change. For 8-bit simulation, the thresholds used for fall detection were rounded to the nearest integer value ($\pm 2$), and acceleration data were scaled for posture analyses by a factor of 10 before low-pass filtering.

### 2.4. Statistical analysis

Fall detection sensitivity was determined for each six fall types separately, resulting in 240 samples. For fall detection specificity, ADL samples from middle-aged and older subjects were combined, resulting in 164 samples. Sensitivity and specificity were calculated using Eqs. (2) and (3):

- Sensitivity $= \frac{TP}{TP + FN} \times 100$
- Specificity $= \frac{TN}{TN + FP} \times 100$

where TP = true positives (detected falls), FN = false negatives (undetected falls), and TP = true positives (ADL samples giving false fall alarm), and TN = true negatives (ADL samples not giving fall alarm).

### 3. Results

The fall detection platform was tested with intentional falls and ADL samples. Fall detection sensitivity and specificity of three different detection algorithms are summarized in Table 2. Specificity, as determined from ADL samples of both middle-aged and older test subjects, was 100% for all algorithms, indicating no false fall alarms. The fall detection sensitivity of the different algorithms, as determined from intentional falls, varied (Table 2).

The best fall detection sensitivity was achieved with algorithm 1 using parameter $SV_{\text{TOT}}$, which detected 97.5% of the test falls. Parameters $SV_{\text{MaxMin}}$ and especially $SV_{\text{V}}$ were more inefficient for impact detection than other parameters. All forward falls, lateral falls, and falls from a bed were detected, while some (n = 6) backward falls remained undetected by algorithm 1 using $SV_{\text{TOT}}$ for impact detection. In four of these cases, end posture was not detected as horizontal even though all the fall events in the test protocol ended up with the subject in a lying posture. In two cases the value of $SV_{\text{TOT}}$ did not exceed the predetermined threshold for impact.

Algorithm 2 involved the detection of start of the fall. This criterion was fulfilled in 95% of the test falls, resulting in a fall detection sensitivity that was slightly lower than for algorithm 1 (Table 2). The biggest difference in fall detection sensitivity between algorithms 1 and 2 was found in falls from a bed.

The most complex fall detection method, algorithm 3, detected from 77% to 78% of falls (Table 2). In 80% of all test falls, velocity $v_0$ exceeded the predetermined threshold. Algorithm 3 was not able to detect falls from a bed.

The effect of restricted data processing capacity on fall detection was tested with algorithm 1 using 16- and 8-bit integer data formats. The fall detection sensitivity and specificity in these simulations are summarized in Table 3. Simulations with 16-bit data format resulted in a high fall detection sensitivity and the specificity remained at 100%. In contrast, data processing in 8-bit format resulted in high fall detection sensitivity but only limited fall detection specificity (Table 3). Most false fall alarms were generated by ‘lying down’ and ‘picking up an object’ activities (data not shown).

### 4. Discussion

This study was performed to evaluate the sensitivity and specificity of fall detection algorithms using a new fall detector prototype and simulated falls of middle-aged test subjects. Activities of daily living performed by middle-aged and older people were used as a reference. This fall detection concept appeared to provide an effective method for automatic fall detection, discriminating various types of falls from activities of daily living, with a sensitivity of 97.5% and a specificity of 100%. The best fall detection sensitivity was achieved with the simplest criteria, based on monitoring the fall associated impact and end posture.

Previously, we used a different device platform and a smaller test group for preliminary testing of the concept [18,19]. The results here are comparable with our earlier studies, showing similar fall detection capabilities. These results are also comparable with other studies, even if they have typically been performed with young volunteers [7–10,12].

Fall detection sensitivities of 70–96% and specificities of 84–100% have been reported for wrist-worn fall detection devices [7,10,12,14,23]. Even though still higher sensitivity and specificity values have been presented for chest-worn [8] or head-worn
accelerometers [9], the attachment site at the waist has been suggested to be optimal as far as usability is concerned [23]. In this study, we used fall detection algorithms with increasing complexity. Some differences in the sensitivity of algorithms were observed, indicating different fall mechanisms for different fall types. All forward falls and over 50% of the backward falls showed the following three fall phases: start of the fall, impact, and horizontal end posture. Falls in the lateral direction, which are associated with a high risk of hip fractures [24], showed a high falling velocity in addition to the three phases mentioned above. In contrast, most falls from a bed did not fulfill the criteria of high falling velocity towards the ground. In overall, quite simple models appeared to be reliable in detecting heterogeneous falls.

Some backwards falls were not detected by impact monitoring. This may partly be caused by the study set-up with intentional falls, since earlier studies have suggested that the squat response reduces impact velocity and impact energy during self-initiated backward falls [25]. Video analyses of our data revealed that in some falls, test subject rolled down with a rounded back, which is characteristic for martial arts falling techniques and is likely to contribute to the reduction of impact forces [26]. In some fall samples the end posture was not recognized correctly. The vertical axis of the accelerometer was not fully optimal for some persons with abdominal obesity, thus resulting in false end posture interpretation. In general, accelerometers have been used for posture detection with high accuracy [10,11]. Personal calibration protocol might decrease inaccuracies related to device attachment.

End posture determination was needed here for specific fall detection, since some ADL samples of both middle-aged and older subjects had values higher than the thresholds for fall-associated impacts (data not shown). This supports the use of both middle-aged and older people for determining fall detection specificity. However, Bourke et al. [8] showed separate ranges of total sum vector values for falls and ADL when measured at the chest. So far, our fall detection simulations in a LabVIEW environment were performed using floating point data format. However, for powerful software implementation, the effect of restricted bit width was studied, showing that data processing in 16-bit data format is efficient with high fall detection sensitivity and 100% specificity. For practical wireless implementation, power consumption should also be optimized. The real-life relevancy of using young or middle-aged test persons instead of older adults in experimental testing of fall detection concepts is still unclear. Older people have longer reaction time when compared to younger people [27]. Middle-aged people show, depending on performed task and measure, both equal and distinguished balance performance when compared to older people [28,29], and they could be considered to mimic the fall events of older people more adequately than young subjects would. In future, fall detection technologies should be validated on a larger scale in real use conditions.

To conclude, the fall detection concept tested here provides an effective method for automatic fall detection. The method can discriminate various types of falls from activities of daily living, with a sensitivity of 97.3% and a specificity of 100%.

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Conflict of interest statement

The authors have no conflicts of interest.

References

Perceived risk of falling among old people receiving home-help services: a matter of mobility, morale and consequence concern?

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Abstract

Objectives: To describe fall-related concern, fear of falling, and associated factors among old people receiving home-help services.

Design: Cross-sectional study.

Subjects: Fifty-one randomly selected community-dwelling old people receiving home-help services, provided by municipality authorities located in the northern part of Sweden.

Methods: The demographical data and the amount of home-help care provided were collected from records. Data accumulated in a face-to-face interview and physical assessment conducted in each participants’ home included perceived risk of falling, mobility, cognition, morale, fall history of falling, and concern about the consequences of falling. To assess the perceived risk of falling, the Falls Efficacy Scale – International (FES-I) and a single question “Are you afraid of falling?” were used. Stepwise multiple regression was performed to analyze variables independently associated to FES-I.

Results: The mean value for FES-I was 30.2 (95% CI 27.3-33.2), and 65 % of the participants had a score indicative of a high level of concern. Fear of falling was reported for about half (59 %) of the participants. Mobility, morale, and concern about the consequences of falling showed to be significantly independently associated to FES-I and the model explained 39 % of the variance.

Conclusion: Fall-related concern and fear of falling are prevalent amongst old people receiving home help, and fall-related concern seems to be associated with mobility, morale, and fears of the consequence of falling. This implies that the perceived risk of falling is a dimension that should be considered when planning home-help services for old people and in fall-prevention programmes.
The perceived risk of falling, expressed as either fall-related concern or fear of falling is reported to be the cause of a significant amount of psychological distress among old people, and is viewed as a pervasive public health problem in the literature [1]. It is reasonable to think that some degree of concern may be rational and have a possible preventive effect, reducing the likelihood of falling [2]. On the other hand, being strongly concerned, and maybe irrationally so, is reported to contribute to a range of unpleasant consequences like loss of confidence and the curtailment of activities, that in turn may result in physical decline [3], influence quality of life [4] and, in fact ultimately, increase the risk of falling [1]. To assess the perceived risk of falling, henceforth referred to just as ‘the perceived risk’, different definitions and methods have been used, and as a result, it has not always been clear what construct was measured, e.g., related constructs such as fear of falling and fall-related self-efficacy have been used interchangeably [5]. The prevalence of fear of falling has been estimated to range between 21 and 83% [1] although it is likely that the variability in the prevalence is partly due to the different definition and methods used.

Although concern about falling is well-researched in community-dwelling old persons [1], little attention has been focused specifically on old persons receiving home-help services [6]. The amount of home-help provided is strongly correlated to ADL dependency cognitive impairments and advanced age [7], as well as to fall incidence [8]. The number of old persons receiving elderly care services have, essentially, been stable since the year 2001. Simultaneously, the number of old people living in residential care has decreased and the number of old people receiving home help has increased [9]. This indicates that many individuals receiving home-help services constitute a transitional group unable to live entirely independently in the community and not requiring full-time residential care, and knowledge of their perception of falling would be valuable.

Fear of falling has been shown to be independently associated with certain demographic factors, such as advanced aged, female sex and fall history [10], mobility limitations, including ADL-limitations [11] as well as gait and balance impairments [12]. Other factors, reported to be strongly associated are poor self-rated health [10], psychological factors, including depression and anxiety [13]. Cognitive function is likely to influence risk the perception of risk among older people with disability and has been controlled for when studying variables related to this process [14].
According to some studies [15, 16], people’s belief about falling and its consequences seems to play a role in fall-related concern. Interestingly enough, this is in line with theoretical reasoning where risk is concerned as risk perception is influenced by fear of the consequences of the event in question [17], and deserves further study. Furthermore, it would be of interest to study whether the construct morale, the definitions of which including both acceptance of oneself and of one’s place in the environment, as well as an optimism about the future or pessimism regarding aging [18] is related to the perceived risk of falling. It seems reasonable that age-related self-esteem and expectations for the future would have an impact on the psychological processes underlying the perception of the risk of falling. This is further emphasized by the fact that morale is related both to self-rated health and depressive symptoms [19], which, in turn, are related to perceived fall risk/to the perceived risk of falling.

Thus, the aims were: 1) to describe fall-related concern as well as fear of falling among old people receiving home-help services, and 2) to investigate which independent associations can be identified between fall-related concern and factors such as age, sex, mobility, cognition, morale, fall history, and concern of the consequences of falling.

Methods

This cross-sectional study, conducted in the northern part of Sweden between September 2009 and May 2010, included community-dwellers aged 65 years and over, receiving home-help services provided by the authorities of three municipalities. The study was approved by the social authorities by the relevant social authorities and the Regional Ethical Review Board in Umeå, Sweden (Dnr 09-131M). All participants gave their informed consent in writing.

A sample, comprised of 184 individuals meeting the inclusion criteria, was randomly selected from the local home-help districts in three municipalities and considered for invitation to participate in the study. Staff familiar with the home-help receivers judged 24 (13 %) individuals unfit to participate, these being individuals who were receiving palliative care or who were easily disturbed or worried by visits by visits from people unknown
to them. The remaining 160 individuals were invited to participate, of whom: 79 (43%) declined to participate, 12 (7%) ceased to be home-help service users, 10 (5%) moved, 6 (3%) died, and 2 (1%) were unavailable. Ultimately, the participation rate was 28%, corresponding to a total of 51 individuals. Those participating did not differ significantly from those who did not, regarding sex (p=0.12), age (p=0.40), and the weekly amount of home-help services (p=0.40).

Data on relating to the age, sex, and weekly amount/quota of home-help care were collected from records provided by the local municipal offices. All other data were collected by assessments and a face-to-face questionnaire-based interview conducted in the homes of the participants. See Table 1 for participant characteristics.

Each individual’s personal ADL (p-ADL) performance was assessed using the Barthel Index, a 10-item index, with a maximum total score of 20 indicating independent performance in all 10 of the items. The scale has been proven for validity and reliability [20].

Mobility was measured with the Short Physical Performance Battery for the lower extremity (SPPB), which consists of three tests: standing in a balanced manner with the feet in side-by-side, semi-tandem and tandem positions for 10 seconds, rising from a chair without hand support; and self-paced walking speed measured over 2.4 m. Each test is scored from 0 (unable to perform the test) to 4, and summed to obtain a total score ranging from 0 to 12. The SPPB has been shown to be reliable and valid [21]. Use of walking aids indoors and outdoors was assessed using one of the items of the Physiotherapy Clinical Outcome Variable instrument (COVS) [22].

Global cognitive function was assessed with the Mini - Mental Statement Examination (MMSE) with a total score of 30. Scores below 24 indicate impaired cognition [23].

Morale was assessed by the Philadelphia Geriatric Centre Morale Scale (PGCM), a questionnaire consisting of 17 items, related to three dimensions: agitation, attitude to own aging and loneliness dissatisfaction. The total score ranges between 0 and 17, with higher scores indicating a higher morale. The scale has been found to have moderate reliability [18].

The interview questionnaire included questions about falls and the history of injury attributable to falls during the previous six-months (involving yes/no responses). To assess
the concern about the consequences of falling, the single question “If you were to fall, would you be concerned about getting hurt?” was used. The question was answered on a 4-point ordinal scale, ranging from 1, corresponding to: no, not concerned, to 4, meaning: yes, very concerned. Self-rated fall risk was assessed by the single-item question “Do you consider the risk for falling within the next 6 months to be low or high “

Fear of falling was assessed by a single-item question “Are you afraid of falling?” using a four grade ordinal response scale ranging from 1: “No”, to 4: “Yes, very much” [24].

Fall-related concern was assessed by the Swedish version of the Falls Efficacy Scale - International (FES-I), a questionnaire containing 16 items related to ADL and social activities, scored on a four-point scale from 1: “not at all concerned”, to 4: “very concerned”. The summed score is calculated and lies in the range 16 and 64. It has been suggested that a score of >23 is indicates a high level of concern about falling [25]. The FES-I has been shown to be reliable and valid [26] and, for the Swedish version, the internal reliability has shown to be excellent [27]. When used among frail elderly people, it is recommended that an interview be arranged to apply the instrument face-to-face [28].

Our sample size calculations showed that, in order to be able to detect a 5 point difference on the FES-I between two groups of equal size, using a significance level of 5 %, a power level of 80 %, and standard deviation estimates from a similar population [29], 46 participants should be included. As we anticipated the possibility of the eventual response rate being as low as 25 %, 184 people were invited to participate.

Descriptive analyses were performed using standard methods depending on the scale properties of each measurement. The FES-I, SPPB, MMSE, and PGCM were treated as ratio scales in the analyses as they are summary scores and the data were approximately normally distributed. On the other hand, the weekly number of hours of home-help services received was described non-parametrically owing to the highly skewed distribution. The correlation between FES-I and the rating for the fear of falling was analyzed using Spearman’s rank correlation.

A stepwise multiple linear regression analysis was used to investigate how the: age, sex, SPPB, MMSE, PGCM, fall history, self-perceived risk of falling and concern about
the consequences of falling (all independent variables) were associated with fall-related concern (dependent variable). The ordinal rating of concern about the consequences of falling was transformed into a dummy variable (reference: grade 1, “not concerned”).

Results

The mean score ± SD for FES-I was 30.2 ± 10.6 and the 95% confidence interval (CI) ranged from 27.3 to 33.2. Thirty-three persons (65%; 95% CI: 52% to 78%) had a score of >23, indicating a high level of concern about falling. For eight of the 16 single items, the median value was ≥ 2, i.e. at least some concern about falls (Fig 1).

Twenty-one of the participants (41%) stated that they were “not afraid” of falling, while 17 (33%) were “somewhat afraid”, 8 (16%) were “fairly afraid”, and 5 (10%) “very afraid”. When combining “somewhat”, “fairly” and “very” afraid, 30 participants (59%; 95% CI: 45% to 72%) expressed fear of falling to some degree. The correlation between FES-I and the four-grade fear of falling rating was rho = 0.35, p = 0.013.

The stepwise multiple linear regression analysis of variables independently associated to FES-I is presented in Table 2. Variables included in the final model were concern about the consequences of falling grade 4 (very concerned), SPPB, and PGCMS. The model explained 39% of the variance of FES-I. The standardized coefficients varied between 0.28 and 0.37, the highest value being for fear of the consequences of injury.

Discussion

Our findings indicate that between about half to three-quarters of old people receiving care services in the home would be expected to exhibit a high fall-related concern, or fear, of falling. These results are in line with the results published by Kressig [12] and Kloscek [24] who found prevalence of 51% and 60% respectively, for old people in senior housing. The mean value of the FES-I found would be expected to exceed the suggested cut-off for a high level of concern [25] by at least four points. Nonetheless, the
findings indicate that a high fall-related level of concern and a fear of falling should be recognized as health problems in this population. This is of great importance since growing numbers of people with severe disabilities and illness are being taken care of in their own homes [7].

The eight activities showing the highest median fall-related concern all seem to entail specific challenges to the postural control system, like walking on slippery or uneven surfaces, going up or downstairs or walking on a slope, taking a bath, reaching above the head and going to the shop. Further studies are needed to investigate the consequences that such fear might have on independent performance or on the avoidance of activities that cause anxiety.

Fall-related concern was weakly correlated to fear of falling, although the prevalence of participants presenting a high level of concern and at least some degree of fear were similar. This indicates that these constructs, although related to some degree, are at least partially separate from one another, and should be treated in a manner consistent with this when it comes to assessing and interpreting their prevalence.

Besides of the expected association with mobility, we found that fall-related concern was related also to morale, and to concern about the consequences of falling. Mobility limitations and related impairments have previously been shown to be strongly correlated to the perception of the risk of falling [12]. Previously not being very well studied, beliefs about the consequences of falls have recently been related to activity avoidance and to concern about falls [15, 16], which is further confirmed by our findings. To the best of our knowledge, morale has not been studied in this respect and, therefore, our findings might open up an interesting perspective. It may seem a bit surprising that age, sex, and fall history did not contribute independently to the regression model, as they have in many other studies [10, 30], however the explanation might be found in the characteristics of the specific population in this study, or in the introduction of factors such as morale which had not previously been studied. Fall history was self-reported, which, of course, may be a limitation in a population in which cognitive impairment is prevalent, on the other hand, one can argue that forgotten falls are less likely to influence fall efficacy. The model explained less than half of the variance, leading to the obvious conclu-
sion that there is more to be revealed about the perception of the risk of falling risk in this population.

The response rate was low and almost reached the worst case scenario envisaged when we calculated the number of individuals invited to participate. However, the non-participants invited did not significantly differ from participants as far as the available data were concerned, and, therefore, we consider the sample to be fairly representative of the population in study. All data collection was performed by experienced assessors, using reliable and valid measures and strict protocols. The multiple regression modelling included only pre-selected variables, and default software settings were strictly used in the stepwise procedures. Regarding the variables excluded in the multiple regression modelling, we found no direct indications of a high risk of type II-errors, judging from the regression coefficients and p-values in the multiple regression models. The largest variance inflation factor (VIF) estimate found for a separate independent variable in the modelling was 1.179, a fact which indicates that multicollinearity had been avoided.

We conclude that high fall-related concern and fear of falling are both prevalent among the elderly receiving home-help care, and that fall-related concern seems to be independently associated with mobility, morale, and fear of the consequences of falling. This implies that the perception of the risk of falling is to be regarded as an important factor related to well-being in this population. For future research, a separation of the constructs fall-related concern and fear of falling is recommended. Studies of associated factors could, preferably, include morale or other indicators of self-esteem, health and expectation of what the future will hold, as well as fear of the consequences of falling.

Acknowledgements

We would like to express our gratitude for all assistance provided by the municipal authorities involved. This study was performed in connection with the Sensorband II Project (304-10948-08) funded by European Regional Development Fund of the European Union under the Interreg IV A North program
References


Table 1. Characteristics of included participants (n=51)

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Age, mean ± SD</td>
<td>82.8 ± 6.39</td>
</tr>
<tr>
<td>Sex, n (%)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>12 (24)</td>
</tr>
<tr>
<td>Female</td>
<td>39 (76)</td>
</tr>
<tr>
<td>Living alone, n (%)</td>
<td>41 (80)</td>
</tr>
<tr>
<td>Home-help services h / week, md (q1,q3)</td>
<td>3.4 (1.0, 8.9)</td>
</tr>
<tr>
<td>Barthel index of ADL (0-20) md (q1, q3)</td>
<td>19 (17, 20)</td>
</tr>
<tr>
<td>SPPB (0-12), mean ± SD</td>
<td>4.3 ± 3.0</td>
</tr>
<tr>
<td>Use of walking aids, n (%)</td>
<td></td>
</tr>
<tr>
<td>Indoors</td>
<td>25 (49)</td>
</tr>
<tr>
<td>Outdoors</td>
<td>43 (84)</td>
</tr>
<tr>
<td>MMSE (0-30), mean ±SD</td>
<td>26.2 ± 3.0</td>
</tr>
<tr>
<td>PGCM (0-17), mean ± SD</td>
<td>12.0 ± 3.6</td>
</tr>
<tr>
<td>Reporting falls previous 6 months, n (%)</td>
<td>23 (45)</td>
</tr>
<tr>
<td>Reporting fall related injuries 6 months, n (%)</td>
<td>15 (30)</td>
</tr>
</tbody>
</table>

SPPB: Short Physical Performance Battery
MMSE: Mini-Mental State Examination
PGCM: Philadelphia Geriatric Center Morale Scale
Table 2. Forward stepwise multiple regression model of variables independently associated to FES-I

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Coefficient (95% CI)</th>
<th>Standardized coefficient</th>
<th>p</th>
<th>Variance inflation factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>43.6 (34.5 to 52.7)</td>
<td>&lt;0.001</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>SPPB</td>
<td>-1.1 (-1.9 to -0.2)</td>
<td>-0.30</td>
<td>0.012</td>
<td>1.08</td>
</tr>
<tr>
<td>PGCM</td>
<td>-0.8 (-1.5 to -0.2)</td>
<td>-0.28</td>
<td>0.017</td>
<td>1.04</td>
</tr>
<tr>
<td>Fall consequence concern, value 4 (ref: value 1)</td>
<td>12.9 (4.6 to 21.1)</td>
<td>0.37</td>
<td>0.003</td>
<td>1.12</td>
</tr>
</tbody>
</table>

Dependent variable: FES-I
Model adj. R square: 0.387, p<0.001
Variables not included: age, sex, MMSE, self-perceived fall risk, falls previous 6 months, fall consequence concern, values 2 and 3
FES-I: Fall Efficacy Scale-International
SPPB: Short Physical Performance Battery
PGCM: Philadelphia Geriatric Center Morale Scale
MMSE: Mini-Mental State Examination
1. Cleaning the house
2. Getting dressed/undressed
3. Preparing meals
4. Taking bath/shower
5. Going to the shop
6. Getting in/out of a chair
7. Going up/downstairs
8. Walking in neighbourhood
9. Reaching above head/to ground
10. Answering phone while ringing
11. Walking on slippery surface
12. Visiting friend/relative
13. Walking in crowds
14. Walking on uneven surface
15. Walking up/down slope
16. Going out to social event

Fig. 1. Median values of separate item of the FES-I. Value 1 indicates “not at all concerned of falling” related to the specific activity, value 2 “somewhat concerned”, value 3 “fairly concerned”, and value 4 “very concerned”. 
Fall-related activity curtailment among old people receiving home-help services

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Abstract

Objectives: To explore fear-induced activity curtailment among old home-help recipients and their expectations on an automated fall alarm system.

Design: Cross-sectional study.

Subjects: Fifty-one randomly selected community-dwelling old people receiving home-help services, provided by municipality authorities located in the northern part of Sweden.

Methods: Fear-induced curtailment of separate activities in daily life, as defined by the Falls Efficacy Scale-International (FES-I), was assessed in a face-to-face interview conducted in the participants’ homes, and related to pre-selected individual factors by step-wise multiple regression modelling. The participants also were asked about their expectations on an automatic fall detector and alarm prototype.

Results: The proportion reporting that they, due to fear of falling, needed assistance to perform a specific activity, or avoided a specific activity, was 57% and 26%, respectively. Such fear-induced need for assistance was associated with morale and mobility, and fear-induced activity avoidance with morale and fall-related concern. When having an automatic fall sensor and alarm system described for them, 74% stated that it would increase their security, 66% that it would decrease their fear of falling and 57% that it would increase their freedom of movement, while 28% feared it could influence their privacy.

Conclusion: Activity-specific fall-related concern seems to be associated with the curtailment of activity for recipients of home-help services. Mobility, overall fall-related concern and morale are factors that are related to the fear-induced curtailment of activities. Further, there seems to be positive expectations in this population on automatic fall alarms.
Falling over and the associated emotional consequence, concern about falling, is common among old people and can be seen as a serious problem, since a high level of concern can have an impact on health [1-3] and threaten the ability to live independently [4]. Many old people have catastrophic thoughts about the possible consequences that a fall might bring [5]. So, in an attempt to avoid falling, they may reduce or avoid activities that they are capable of performing [1]. This strategy might lead to inactivity in the long-term, and subsequently enhance functional deterioration [6], restriction of social engagement [7] and, eventually, an increase in the risk of falling [6]. The prevalence of fear-related restriction on the activities of community-living old people has been estimated from 19 % to 56 % [7-10].

If one shifts the focus from general populations of old/people living in the community to old people living in their own homes and receiving home-help services, to our knowledge, only a few studies have been made [9], that have addressed fall-related restriction of activities. This population is of particular interest because we can expect that over the coming years, a growing number of old people will receive home-help services in the event of them becoming disabled, instead of moving to residential care facilities; a trend that is obvious currently in Sweden [11,12]. The incidence rate for falls among home-help recipients needing personal ADL support seems to be close to the estimates reported among old people living in residential care facilities [13-15], and more than half of home-help recipients report having serious concerns about falls [16]. Fletcher [9] found that 41 % of home-help recipients in Canada restricted their activities, particularly those outdoors. This may point out that fear-related concern is particularly prevalent when it comes to activities that challenge a person’s postural control systems. Furthermore, it was found that female sex, having mobility restrictions, being alone for long periods of time, and having had frequent falls were factors independently associated with restriction on activities. In a study of old people living in senior housing [7], it was found that 56 % of those afraid of falling curtailed their activities, and factors independently associated to this were having less support, knowing someone who had fallen, and not communicating about falls.

People living in residential care facilities or receiving home-help services most often fall when they are not being observed by staff or relatives [13,17], which increases the
risk of them lying helpless after a fall, should they not be able to call for help. Fall-related events are often not reported if the faller recovers without serious injuries, but they may still result in undetected injuries, anxiety and distress [18]. Recently, an automated fall sensor system has proved sensitivity and specificity regarding the detection of deliberately staged falls in an experimental setting [19]. Thus, this concept would seem to provide an effective means of sending an alarm to staff or relatives in the event of a fall, and might, therefore, contribute to an increased feeling of safety and security. However, this system still needs to be validated in real-life settings, and the users’ expectations of such a concept need to be explored.

In a previous paper on this topic [16], we described fall-related concern among old people receiving home-help services, as assessed by the Falls Efficacy Scale – International (FES-I) [20] a sum score examining fall-related concern regarding 16 specific activities in daily life. In this paper, using the same sample, we aimed to: 1) describe how curtailment of the independent performance of specific activities of the FES-I was related to fall-related concern, 2) describe how curtailment attributable to a of fear of falling while performing specific activities is related to a set of pre-selected individual factors, and 3) explore the expectations that home-help recipients have of an automatic fall-sensor and alarm system regarding its potential to increase self-perceived safety and security.

Methods

This study was cross-sectional, and included community-dwellers aged 65 years and over, all of whom were receiving home-help services provided by the social authorities of three municipalities. The study was approved by the relevant social authorities and by the Regional Ethical Review Board in Umeå, Sweden (Dnr 09-131M). All participants gave their informed consent in writing.

Participants

The home-help service records of the municipality offices were used to obtain the names of 184 individuals meeting the inclusion criteria. These people were randomly selected
from the records and invited to participate in the study. Staff who were familiar with the recipients of home-help services judged 24 (13%) of the individuals to be unfit to participate; including those receiving palliative care or who were easily disturbed or worried by visits from unfamiliar people. The remaining 160 individuals were invited to participate, of whom 79 (43%) declined to participate, 12 (7%) had ceased to use home help services before they being interviewed/contacted, 10 (5%) had moved, 6 (3%) had died, and 2 (1%) were unavailable. Thus, the final total was 51 (28%) participants (Table I). Those participating did not differ significantly from those who did not in terms of their sex (p = 0.12), age (p = 0.40), and the weekly amount of home-help service provided (p = 0.40).

Data collection
Demographic data regarding the sex and age of the respondents, as well as the amount of home-help care provided/supplied were collected from records provided by the local municipal offices. All other data were obtained by assessments using standardized instruments and through a face-to-face questionnaire interview, completed by trained persons in the homes of the participants.

The Swedish version of the Fall Efficacy Scale - International (FES-I) was used to assess fall related concern [21]. The questionnaire includes 16 items representing indoor and outdoor activities in daily life. The items are scored on a 4-point scale from 1 = not at all concerned to 4 = very concerned, therefore the total score ranges from 16 to 64. The FES-I has been shown to be reliable and valid [22], as has the Swedish version [21]. When frail older persons are being assessed, it is recommended that the instrument is used in face-to-face interviews [23]. In order to assess the curtailment of activity, for each one of the items, except “answering the phone”, the participants were asked whether the activity was “performed independently”, “performed with assistance”, or “avoided”. If the response was either “performed with assistance” or “avoided”, the participants were asked to indicate whether this was because of “fear of falling” or “some other reason”. The numbers of activities “performed with assistance because of fear of falling” and “avoided because of fear of falling” were summed up to obtain two separate scores for the curtailed activities.
Personal ADL (p-ADL) performance was assessed by the Barthel Index, a 10-item index with a maximum total score of 20 indicating independent performance of all 10 items. The validity and reliability of the scale have been proved [24].

Mobility was measured with the help of the Short Physical Performance Battery for the lower extremities (SPPB). The SPPB consists of three tests: standing balance; 5 repetitions of rising from a chair; and self-paced walking speed over 2.4 m. Each test is scored from 0 (unable to perform) to 3, with a total score that ranges from 0 to 12. The higher the score, the better the function of the person being assessed. The SPPB has been shown to be reliable and valid [25]. Use of a walking aid indoors and outdoors was determined by one item in the Swedish version of the Physiotherapy Clinical Outcome Variable instrument (S-COVIS) [26].

The overall cognitive function was assessed with the Mini-Mental Statement Examination (MMSE) [27] with a total possible score of 30. Scores below 24 indicate impaired cognition [28].

Morale was assessed by the Philadelphia Geriatric Centre Morale Scale (PGCM) [29], a questionnaire consisting of 17 items, related to three dimensions, agitation, attitude to own aging and lonely dissatisfaction. The total score ranges between 0 and 17, higher values indicating a higher morale. The scale has been found to have moderate reliability [29].

The prevalence of falls and fall-related injuries during the previous six months were self-reported, again using yes/no responses. The single question “If you fall, are you concerned that you will get hurt?” was used to assess the concern the person had about the consequences of falling (referred to henceforth as the concern of fall-related consequences). The question was answered on a 4-point ordinal scale ranging from 1; no, not concerned, to 4; yes, very concerned. Self-rated fall risk was assessed by the single-item question “Do you consider the risk for falling within the next months to be low or high”.

Finally, the participants were presented the idea of using a waist-worn automatic fall alarm device, sending an alarm if a fall should take place via the Internet to the standard alarm system. They were then asked whether they felt that such a device would: increase their security, reduce their fear of falling, violate their privacy, or increase their freedom of movement. The questions posed were based on the results of a study investigat-
ing/examining old people’s experiences of using mobile safety alarms [30] and the response alternatives were “agree” (completely or in part) or “do not agree at all”.

Data analyses
Descriptive analyses were performed using standard statistical methods chosen to match the scale properties of each of the variables assessed. FES-I, SPPB, MMSE, and PGCM were treated as ratio variables as they are summary scores and the data were approximately normally distributed. In contrast, the amount of home-help services received was described non-parametrically due to a skewed distribution.

A stepwise multiple linear regression analysis was used to investigate how the age, sex, FES-I, SPPB, MMSE, PGCMS, fall history, self-rated risk of falling, and concern of fall-related consequences (independent variables) associated with the numbers of activities “performed with assistance because of fear of falling” and “avoided because of fear of falling” (dependent variables). The ordinal variable for the concern of fall-related consequences was dichotomized to “not concerned” (value 1) or “concerned” (values 2-4, depending on the degree of concern).

The SPSS package v. 17.0 was used for the computations and the significance level was set to < 0.05.

Results
The mean total score of the FES-I was 30.2 with a 95 % confidence interval (CI) ranging from 27.3 to 33.2. Of the participants, 65 %; (95 % CI: 52 % to 78 %) scored higher than the threshold value for a serious concern [31].

Figure 1 shows two different profiles of median values for the FES-I items, depending on whether the activity related to the item was performed independently or not. Except for the three items “taking a bath/shower”, “visiting friends/relatives” and “going out to a social event”, those who reported that they did not perform the activity independently consistently had higher median values for the level of fall-related concern expressed for the activity under consideration.
As far as independent activity performance was concerned, 11 out of 15 activities were associated with a median value for the fall-related concern they caused of 1, indicating that they posed no concern to the respondents. For more demanding mobility-related activity items, such as “going to the shop”, “walking on slippery and uneven surfaces” and “walking up and down a slope”, the median values indicated “some concern”.

Concerning the non-independent activity performance, the highest median fall-related concern values were observed for the more mobility-demanding items, like “walking in the neighborhood”, “going up and down the stairs”, “reaching above head or ground”, “walking on slippery” and “uneven surface” and “walking up or down slopes”. Only two activities, “visiting friend/relatives” and “going out to a social event/to social events”, resulted in a median value indicating “no concern” among those who were not able to perform the activities independently.

Twenty-nine participants (57%) reported needing assistance to perform at least one of the activities because of a fear of falling and two of them reported curtailing as many as six activities in this a way. Thirteen participants (26%) stated that they avoided at least one activity because of fear of falling and one participant avoided a total of six activities for this reason.

The result of the multiple linear regression analysis of variables independently associated with the numbers of activities “performed with assistance because of fear of falling” is presented in Table 2. Variables included in the model were PGCM and SPPB. The model explained 22% of the variance. The standardized coefficients varied between -0.27 and -0.41, the highest absolute value for PGCM.

Table 3 presents the multiple linear regression analysis of variables independently associated with the number of activities “avoided because of fear of falling”. Variables included in the model were FES-I and PGCMS, The model explained 21% of the variance. The standardized coefficients were 0.31 and -0.28, the highest absolute value for FES-I.

When expressing their expectations on an automated fall alarm system, 74% of the participants agreed that it would increase their feeling of security, 66% agreed that it would reduce their fear of falling, 57% stated that it would increase their sense of freedom of movement, while 28% feared that it could influence their privacy.
Discussion

In this study, we found that curtailing the performance of independent activity seems to be associated with activity-specific fall-related concern amongst old recipients of home-help services. This appears to be most strongly expressed for the activities that put the most demand on motor control systems, e.g. walking on a slippery surface. Mobility, general fall-related concern, and morale seem to be independently associated with fear-induced curtailment of activity. The expectations of an automatic fall alarm system are predominantly positive, however there is some concern regarding its possible violation of privacy.

The result showed that more than half of the home-help recipients would be expected to express a high fall-related level of concern, according to the FES-I and its threshold value for serious concern [31]. However, as the FES-I questionnaire contains a combination of both indoor and outdoor activities that comprise different challenges to the maintenance of postural control, it is unreasonable to assume that each item will contribute equally to the overall concern about falling. In line with studies conducted previously [32, 33] the most demanding activities, such as walking on slippery and uneven surfaces were perceived to be the most fear-inducing and these results point out the importance of the type of activity when interpreting a person’s fear of falling. Surprisingly, and in contrast with results reported previously [4], social activities, like visiting friends and going to social events did not seem to be especially feared. A possible explanation for our finding might be that, in these situations, the respondents would not be alone, and it may be that they rely on others for their safety and for receiving help in the event that they were to fall. A similar pattern where fear of falling for home environment activities did not correspond to fear of falling for community-based activities was found in a study of community-living old people [33].

In this study, the median values for the items of the FES-I were almost consistently lower for those reporting that they performed the activities independently than for those who did not. Suzuki et al [34] found daily life activities to be moderately fear-inducing among persons requiring “some” assistance, while among those needing “complete” assistance, the activities very frightening.
A detrimental consequence of being concerned about the possibility of falling over is the resultant curtailment of activity. In this study, more than half of the participants relied on assistance for at least one activity because of a fear of falling and about one in four avoided at least one activity for the same reason, and several had curtailed more than one activity. In a study by Fletcher [9], conducted among old persons receiving home-help services, 41% were reported to restrict their activities owing to a fear of falling, particularly outdoor activities. In a prospective population-based study [3], it was found that 15% restricted three activities or more. Moreover, such severe activity restriction was also shown to be a predictor for further decline in the ADL-disability and an accelerated decline in lower extremity performance. Findings in a qualitative study [35] indicate that although the activities that are avoided initially are the non-essential ones, this still seems not to impede the life-space of the individuals. It also was argued that a concern about falling can to some degree be protective, meaning that the person would be more attentive and would carry out the activity with caution.

In our study, we found mobility and morale to be significantly associated with the number of activities performed with assistance because of a fear of falling. Interestingly, only the psychological factors, morale and overall concern of falling, were associated to the number of activities avoided. Our separation of the activity curtailment into dependency on assistance or activity avoidance might have helped to reveal different patterns of variables related to this curtailment, not previously shown. Previously [16], we have described the association between morale and concern about falling among home-help recipients, and in this study morale seemed to be linked both with fear-induced assistance dependency and avoidance of activities. It seems reasonable that this construct, entailing age-related self-esteem and expectations for the future [29], would have an impact on the psychological processes underlying the perception of the risk of falling and its consequences for activity performance. The other psychological factor connected to the degree of activity curtailment was the overall concern of falling (sum score of FES-I), which has been linked to restriction on activity in several studies [8-10]. In our analyses, this association was found only regarding activity avoidance and not assistance dependency. On the other hand, mobility limitations, previously reported to be strongly associated to activity restrictions [5], was in our study only associated to assistance dependency and not
to activity avoidance. This indicates that different factors mediating concern about falls might have different impact on activity-related consequences and should be studied further in this respect.

The positive perception of the potential of an automatic fall alarm intended to increase the security of frail elderly people and thereby to enhance their freedom of movement is interesting. As one would anticipate, it seems to be important for most home care recipients that falls will be detected by staff rapidly, presumably to ensure that they receive help without delay when it is needed. This is in line with the findings reported in a recent study regarding mobile alarm systems [30]. However, it should be noted that several responders expressed concern about a possible violation of privacy, pointing out that individual needs and circumstances must be taken into account when use of such devices is considered.

The response rate in this study was low; however, the non-participants invited did not significantly differ from participants as far as the available data were concerned. Therefore, we consider the sample to be fairly representative of the population in study. A larger sample would have been preferred, however, since there are indications of possible type-II errors. Judging from the regression coefficients and p-values in the multiple regression analysis of fear-related dependence on assistance, considering the variables age and self-rated fall-risk, there is a risk that such errors occurred. The sample for this study was identical to that of a previous paper [16] and the required minimum sample size was decided from a power analysis corresponding to the aims of the previous study. All data collection was performed by experienced assessors, using strict protocols and reliable and valid assessment instruments. The questions posed in conjunction with the curtailment of activity and the expectations of an automatic fall alarm were not tested for reliability or validity. Nevertheless, they resembled questions used in previous studies and were subject to pilot testing. The multiple regression modelling included only pre-selected variables, and default software settings were strictly applied in the stepwise procedures. The largest estimate of the variance inflation factor (VIF) found for a separate independent variable in the modelling was 1.432, indicating that multicollinearity had been avoided.
We conclude that activity-specific fall-related concern seems to be associated with the curtailment of activity for recipients of home-help services. Mobility, overall fall-related concern and morale are factors that are related to the fear-induced curtailment of activities. This implies that feelings of insecurity, a high level of fall-related concern and fear-induced activity curtailment should be recognised and regarded as factors that have a significant detrimental potential to influence independence and well-being in the population investigated. Automated fall detecting and alarm systems might be valuable in order to reduce the concern about falling, however privacy-related concerns must be considered. An additional and more offensive approach to deal with fear-induced activity curtailment would be to try alleviating some of the factors causing fear and concern and, therefore, future research on how the fear is mediated and intervention trials are requested.

Acknowledgements

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References


<table>
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<th>Table 1. Characteristics of included participants (n=51)</th>
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<td>Sex, n (%)</td>
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<tr>
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</tr>
<tr>
<td>Female</td>
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<tr>
<td>Living alone, n (%)</td>
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<tr>
<td>Home-help service h / week, md (q1,q3)</td>
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<tr>
<td>Barthel index of ADL (0-20) md (q1, q3)</td>
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<tr>
<td>SPPB (0-12), mean ± SD</td>
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<tr>
<td>Use of walking aids, n (%)</td>
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<tr>
<td>Indoors</td>
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<tr>
<td>Outdoors</td>
</tr>
<tr>
<td>MMSE (0-30), mean ±SD</td>
</tr>
<tr>
<td>PGCM (0-17), mean ± SD</td>
</tr>
<tr>
<td>Reporting falls previous 6 months, n (%)</td>
</tr>
<tr>
<td>Reporting fall related injuries 6 months, n (%)</td>
</tr>
</tbody>
</table>

SPPB: Short Physical Performance Battery
MMSE: Mini-Mental State Examination
PGCM: Philadelphia Geriatric Center Morale Scale
Table 2. Forward stepwise multiple regression model of variables independently associated to number of activities performed with assistance because of fear of falling

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Coefficient (95% CI)</th>
<th>Standardized coefficient</th>
<th>p</th>
<th>Variance inflation factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>4.67</td>
<td></td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.03 to 6.34)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PGCM</td>
<td>-0.21</td>
<td>-0.41</td>
<td>0.002</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>(-0.34 to -0.08)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPPB</td>
<td>-0.16</td>
<td>-0.27</td>
<td>0.039</td>
<td>1.01</td>
</tr>
<tr>
<td></td>
<td>(-0.32 to -0.01)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dependent variable: Number of activities performed with assistance because of fear of falling
Model adj. R square: 0.223, p: 0.001
Variables not included: age, sex, MMSE, falls previous 6 months, self-rated fall risk, FES-I, concern of fall-related consequences
FES-I: Fall Efficacy Scale-International
SPPB: Short Physical Performance Battery
PGCM: Philadelphia Geriatric Center Morale Scale
MMSE: Mini-Mental State Examination
Table 3. Forward stepwise multiple regression model of variables independently associated to number of activities avoided because of fear of falling

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Coefficient (95% CI)</th>
<th>Standardized coefficient</th>
<th>p</th>
<th>Variance inflation factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.61 (-1.25 to 2.48)</td>
<td>0.510</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PGCM</td>
<td>-0.10 (-0.20 to -0.00)</td>
<td>-0.28</td>
<td>0.047</td>
<td>1.17</td>
</tr>
<tr>
<td>FES-I</td>
<td>0.04 (0.00 to 0.07)</td>
<td>0.31</td>
<td>0.032</td>
<td>1.17</td>
</tr>
</tbody>
</table>

Dependent variable: Number of activities performed with assistance because of fear of falling
Model adj. R square: 0.206, p: 0.002
Variables not included: age, sex, MMSE, falls previous 6 months, self-rated fall risk, SPPB, concern of fall-related consequences
FES-I: Fall Efficacy Scale-International
SPPB: Short Physical Performance Battery
PGCM: Philadelphia Geriatric Center Morale Scale
MMSE: Mini-Mental State Examination
Figure 1

Fig 1. Profiles of median values for separate FES-I items, depending on whether the activity related to the item was performed independently (diamonds and dashed line) or not independently (squares and solid line).
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