PHYSICAL ACTIVITY AND FALLS IN OLDER PERSONS

Development of the Balance Control Difficulty Homeostasis Model

Gert Jan Wijlhuizen

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Cover Image:
Front: Parents of author observing the balance of a Tippe Top.

Back: Wolfgang Pauli and Niels Bohr studying the balance of a Tippe Top. The picture is taken at the opening of the new institute of physics at the University of Lund on May 31 1951. Credit: Photograph by Erik Gustafson, courtesy AIP Emilio Segre Visual Archives, Margrethe Bohr Collection (www.aip.org/history/esva).

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Contents

Chapter 1

Introduction

Incidence and consequences of falls

Among older persons many falls[1] happen each year which have a serious impact on their health, independence and wellbeing. Several studies showed that about one third of community dwelling older persons in the age of 65 years and over fall each year at least once as shown in table 1.

Table 1 *Percentage of fallers among older persons participating in six different studies*

Study	Country	Target group N; Age in years	Study design	Percentage Fallers
Prudham, D (1981)[2]	UK	N=2793 65+	Retrospective study (1 year)	28%
Campbell, AJ (1981)[3]	New Zealand	N=553 65+	Retrospective study (1 year)	33%
Tinetti, ME (1988)[4]	USA	N=326 70+	Telephone Interview	32%
Blake, AJ (1998)[5]	UK	N=1042 65+	Retrospective study (1 year)	35%
Downton,JH (1991)[6]	UK	N=203 75+	Retrospective study (1 year)	42%
Stalenhoef, PA (2002)[7]	The Netherlands	N=311 70+	Telephone interview (1 year)	33%

The agreement between the percentages of falls in the different studies is remarkable if we consider that these studies were conducted in various countries where physical activity patterns and environmental circumstances may vary substantially. For instance in The Netherlands, many older persons are used to frequent outdoor walking and bicycling as in the USA traveling may be more often performed by car. In addition, climate and pavement conditions may vary significantly between countries. In line with the data in table 1, in international reviews it is generally postulated that about 30% of older persons aged 65 years and older fall at least once each year.[8,9] This implicates that falling is an event that happens to a large proportion of older persons, but the frequency per person per year is generally low. Two thirds of all fallers during a year only fall once.[12] Although this might imply that for most older persons falling does only occur occasionally, its consequences may be serious. Approximately 10% of all falls result in serious injury,[13,14] of which 50% are fractures.[4,13,14]

[1] As recommended by the Prevention of Falls Network Europe (ProFaNE) and Outcome Consensus Group, a fall should be defined as 'an unexpected event in which the participants come to rest on the ground, floor, or lower level'.[10,11]

Consequently, falls put a heavy burden on the health of individual older persons and on the capacity of the healthcare system in many countries.
In the Netherlands, due to a fall about 86,000 older persons (55+) are treated each year by a general practitioner, 88,000 are treated at the emergency room of hospitals, 32.000 are admitted to the hospital and 1,800 falls are fatal.[15]
At the European level no direct figures are available about hospital admission due to falls among older persons (55+). Therefore, an estimation is made from the following available data. In the EU region of 27 countries every year about 5.5 million elderly (65+) sustain an injury severe enough to seek medical care, out of whom about 2 million are ending up in a hospital.[16] It is estimated that older adults (65+) are hospitalized for fall-related injuries five times more often than they are for injuries from other causes.[17] Therefore, in the EU each year about 1.6 million older adults are admitted to the hospital after a fall. In addition, in the EU region of 27 countries, there are probably nearly 40,000 deaths from falls among elderly each year.[16] Persons at high age are at highest risk for fatal falls; persons aged 80 and over have a 6-fold higher mortality compared to elderly 65-79 years, as they are not only more likely to fall but also more frail than those aged 65-79.[16]
Apart from the injurious consequences, falls can also have serious social and psychological consequences. Recurrent falls are a common reason for admission of previously independent older persons to long-term care institutions.[18,19] Fear of falling and the post-fall anxiety syndrome are also well recognized as negative consequences of falls. The loss of self-confidence to ambulate safely can result in self imposed functional limitations.[20-22] This tendency further contributes to deconditioning, weakness and abnormal gait and in the long run may actually increase the risk of falls.[23] In the next section factors that contribute to the risk of falling are presented.

Risk factors for falls

The variety of proposed risk factors for falls is huge, over 400 potential risk factors are suggested.[24] This large number reflects the complexity of the aetiology of falls as well as the lack of theoretical frameworks of falls causation which might limit the number of factors which should be addressed in risk factor analysis. Review studies on risk factor analyses for falls showed however, that a selection of main risk factors can be identified. In table 2 these fall risk factors, and their relative importance, are listed as reported by Rubenstein.[23]

Table 2 *Important individual risk factors for falls: summary of 16 controlled studies*

Risk factor	Significant/ Total[a]	Mean RR–OR[b]	Range of RR-OR[d]
Muscle weakness	11/11	4.9 (8)[c]	1.9–10.3
Balance deficit	9/9	3.2 (5)	1.6–5.4
Gait deficit	8/9	3.0 (5)	1.7–4.8
Visual deficit	5/9	2.8 (9)	1.1–7.4
Mobility limitation	9/9	2.5 (8)	1.0–5.3
Cognitive impairment	4/8	2.4 (5)	2.0–4.7
Impaired functional status	5/6	2.0 (4)	1.0–3.1
Postural hypotension	2/7	1.9 (5)	1.0–3.4

[a] Number of studies with significant association/total number of studies looking at each factor.
[b] Relative risks (prospective studies) and odds ratios (retrospective studies).
[c] Number in parenthesis indicated the number of studies that reported relative risks or odds ratios.
[d] Range of Relative Risks or Odds Ratio's found in the studies reporting them (c).

Rubinstein showed that the most important of these risk factors is muscle weakness, with mean RR-OR of 4.9; indicating an increased risk of falling for persons with muscle weakness. Also problems with balance and gait were identified as important risk factors. Not included in table 2 is the use of medications, particularly the psycho-active medications, which has also been identified as a risk factor for falls (RR=1.5-1.7).[23]

The risk factors for falls that are established are mainly related to health deficits (also called intrinsic factors) which reduce the capability of older persons to control balance, as shown in table 2.[23] However, one might also expect that influences from the environment on balance control of older persons, like obstacles on pavements and skiddyness of floors may determine the risk of falling. From research, the evidence for the impact of these environmental (also called extrinsic) factors on the risk of falling among older people is limited.[9] Some studies have reported that between 30% and 50% of falls among community dwelling older people are due to environmental causes and others that 20% of falls are due to major external factors (those that would cause any healthy adult to fall).[25,26]

Extrinsic risk factors include:

- Environmental hazards (poor lighting, slippery floors, uneven surfaces, etc.),[26]
- Footwear and clothing,[26]
- Inappropriate walking aids or assistive devices.[27]

In addition to the intrinsic and extrinsic risk factors for falls a third factor is involved in the risk of falling. This third factor is a behavioural factor which represents the exposure to the danger which is formed by the reduced balance control capability and/or balance control demands as presented in figure 1. The conceptual relevance of exposure can be illustrated by taking the example of a person who has reduced balance control capability but at the same time avoids climbing stairs and walking in crowded areas. By avoiding the exposure to these demands, the person has lower falls risk compared to a comparable person who does not avoid them. In the extreme situation that a person is not exposed to any of the intrinsic and extrinsic risk factors the falls risk equals zero.

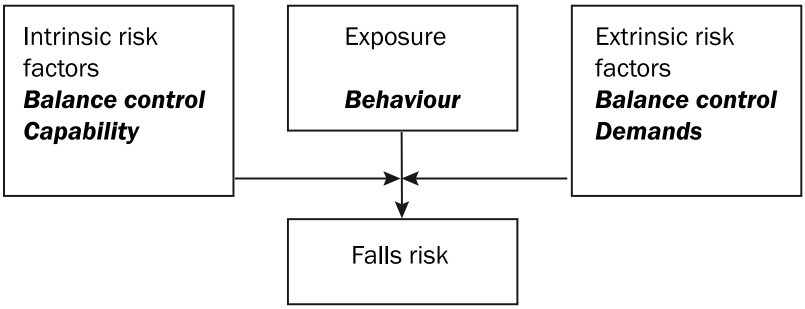

Figure 1 *Main clusters of risk factors for falls (intrinsic, extrinsic) and the involvement of exposure as a precondition for falls risk being >0*

Therefore, exposure to a danger is a precondition for an accident (fall) to happen. However, the issue of exposure to accident (falls) and injury risk is only very seldom addressed in the field of falls research. Therefore, special attention is given to this issue in the following section.

Accident or injury risk and exposure

From a general perspective, the safety of a system (or person) is the product of the probability of having an accident or injury given a unit of exposure (also called accident or injury risk) and the observed level of exposure.[28] A unit of exposure can be regarded as a trial. The result of such a trial is the occurrence or non-occurrence of an accident.[29]

In most of the domains of injury prevention (traffic, occupation and sports, consumer products), several expressions are applied to indicate the accident or injury risk. First of all, the population incidence (number of cases per 1000 person-years) is used, but also the number of cases per 1000 person-hours of involvement in related activities.[30-33] In traffic also the number of cases per 1000 person-miles driven is used as an expression of accident risk.[30,34,35] The denominator in each of the expressions, except for the population incidence, is used as a measure of exposure to the danger that is involved in participation in the activities related to the domains.

The significance of including exposure data in risk analysis is addressed by Hale and Glendon[36]: "If a person carries out a particular activity many times and occasionally it goes wrong enough to result in an accident, very different interventions will be necessary to improve matters, compared with instances where a person carries out an activity infrequently, but it almost always goes wrong. Data on the exposure to the hazard or on demands for specific actions must therefore form as fundamental a part of the analytical database of health and safety as records of accidents and occupational diseases."[36]

Within the domain of home accidents, measures of exposure are not commonly applied and reported in literature. Specifically, in the field of falls prevention among older persons, the risk of falls is commonly only expressed as the number of falls or fallers per 1000 person-years, as recommended by Gillespie[37] and Lamb et al.[10]

No measure of exposure to falls risk is applied in this field, although Todd and Skelton[9] addressed the issue within the discussion on risk factors: "Some studies suggest a U-shaped association, that is, the most inactive and the most active people are at the highest risk of falls.[38,39] This reveals the complex relationship between falls, activity and risk. The type and extent of environmental challenges that an older person chooses to embrace interact with the person's intrinsic risk factors."[9] According to Skelton[40] and Jorstad-Stein et al.,[41] apart from beneficial balance control effects, the level of physical activity of persons can be regarded as a general measure of their exposure to hazards which put demands on balance control.

These arguments suggest that older persons might reduce their falls risk by withdrawing from physical activities which they perceive as too dangerous (too demanding) compared to their capability to control their balance. Stated this way, it means that persons might mask their difficulty in controlling their balance by reducing exposure to hazards (i.e.: by reducing physical activity).

In conclusion, the relevance of exposure to hazards as a factor which is involved in falls risk is generally acknowledged, but it has not been addressed systematically in scientific research. Therefore, it seems that in falls risk assessment the apparent significance of exposure requires further exploration. In this thesis this issue will be addressed as described in the next section.

Aim and outline of the thesis

The aim of the thesis is to explore, for falls risk research in older persons, the significance of the level of physical activity as a measure of exposure.
Three prospective follow-up studies were performed which contributed to this exploration in the period between 1994 and 2005. The main characteristics of these studies are listed in table 3.

Table 3 *Main characteristics of the prospective follow-up studies from which the data were used in several chapters of this thesis.*

Prospective follow-up study	Start, Follow up period, Community	Number and age of participants*	Type of participants	Falls registration	Data used in Chapters
'Safety observed study' (Wijlhuizen et al.)[42]	1994, 15 months, Leiden	1055 (65+)	Community dwelling	Telephone each month	2,5
'Safety in your own hands study' (Wijlhuizen et al.)[43]	1999, 2 x 10 months, Sneek, Heerenveen, Harlingen.	2080 (65+)	Community dwelling	Telephone each month	2,3,4,5
'Heerenveen night time falls prevention study' (Wijlhuizen)[44]	2004, 10 months, Heerenveen, Smallingerland.	771 (70+)	Community dwelling	Telephone each month	5,7

* At the start of the follow-up period

Before conducting the first prospective cohort study, the 'Safety Observed Study',[42] in 1994, we required an innovative approach for longitudinal registration of falls among older persons. The main argument was that frequent registration among about 1000 older persons would require very time-consuming procedures if it was performed as usual by mail (diaries) or personal telephoning. Therefore, we developed and applied a new method to register falls in large cohorts of older community dwelling persons, using interactive voice response technology: the Telephony Inquiry System (TIS).
In chapter 2 the procedures and some results of the application of the TIS are reported, indicating its feasibility as a method for falls registration.
In 1999, we applied the TIS in the 'Safety in your own hands study'.[43] In this study, which is described in chapter 3, we evaluated the effect of a multifactor community intervention to reduce falls among older persons in Sneek in comparison to two

control communities (Harlingen and Heerenveen). The results of this study were interpreted by suggesting that in Sneek the intervention resulted in changes in indoor and outdoor physical activity (exposure), compared to the control group. At the same time, we assumed a relationship between the level of outdoor and indoor physical activity and the number of outdoor and indoor falls. No such data were found in literature, indicating the need for studies on the relationship between outdoor and indoor physical activity (exposure) and falls. Therefore we conducted two such studies, which are described in the chapters 4 and 5.[a,b]
In chapter 4, the association between the 24 hour distribution of the level of physical activity in the home and falls in the home is addressed. Subsequently, in chapter 5[a] the relationship between the level of outdoor physical activity (walking and bicycling) and outdoor falls during walking and bicycling is explored. Chapter 5[b] is a rebuttal on two letters which questioned the correct use of the term 'mediation' in our paper; the authors expressed in their letters the need for theoretical considerations about the causal relationship between fragility, fear of falling, physical activity and falls. Because no such causal model was available from literature, a general outline of a hypothesized causal model of falls is described in this chapter. Subsequently, a more elaborate conceptual model of falls is formulated in chapter 6, from the perspective of individual behaviour in the control of balance; the Balance control Difficulty Homeostasis model of falls (BDH-model). This new model is derived from the TCI model of Fuller,[45] about driver behaviour. Based on the BDH-model, the application of a measure of exposure in the outcome variable in falls research is advocated.
Finally, in a prospective follow-up study, the 'Heerenveen nighttime falls prevention study',[44] data on balance control difficulty, physical activity and falls were obtained. Based on these data, in chapter 7 we compared two falls risk outcome measures in relation to balance control difficulty; the incidence of falls per 1000 person-years and per 1000 physically active person-days. In chapter 8 the main results of the studies are summarized and discussed.

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Chapter 2

Automatic registration of falls and other accidents among community dwelling older people: feasibility and reliability of the Telephone Inquiry System

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Int J Inj Contr Saf Promot 2006; 13:58-60

Abstract

Introduction and purpose

The longitudinal registration of accidents, including falls, among people aged 65 and older is both time-consuming and expensive. For this reason, a computerised method for telephone accident registration, 'Telephone Inquiry System (TIS)', was developed and its feasibility (participation, successful dialogues) and reliability (distribution of accidents regarding location, falls requiring medical attention, and falls resulting in fractures) were evaluated.

Method

The TIS is an Interactive Voice Response computer system by which people are telephoned and asked about involvement in accidents and falls in a structured automatic dialogue. If people reported involvement in an accident, details about the circumstances were asked personally by telephone. It was tested in two prospective follow-up studies among community dwelling older people aged 65 and older in the Netherlands between 1994 and 2003.

Results

Of the 3,500 and 8,650 people invited to participate in the two studies, 30.1% and 24.0% did, respectively. In total, the TIS made 48,966 attempts to have an automatic dialogue with respondents, of which more than 70% were successful. Sixty percent of the accidents happened in and around the home. Twenty-five percent of the falls required medical attention and at least 3.3% resulted in a fracture.

Conclusions

The TIS appears to be a feasible and reliable method for semi-automatically registering accidents among community dwelling older people. Valid comparison of data between countries and communities is made possible because the registration is not influenced by differences in patient flows and the questions and procedures are highly standardised.

Introduction

Longitudinal registration of accidents, in particular falls, among older people has been used in many studies to identify risk factors or to evaluate interventions.[1-6]
Two methods of registration are available. First, direct telephoning, which is usually combined with the use of a fall-diary. Second, postal reports, where participants mail information about their falls on a postcard and are telephoned to remind them to do so. It is important to gather accident information frequently in order to minimize underreporting due to forgetting. However, acquiring accident information from large numbers of participants is time-consuming. Therefore, a telephone accident registration system was developed that would reduce the active involvement of the participant and minimizes administration. The system, which operates almost entirely automatically, is called the Telephone Inquiry System (TIS). The TIS is an interactive voice response computer system that telephones people and asks questions in a structured dialogue. The TIS telephones people once per month and asks them whether they have had an accident (falls, burns, collisions, etc.) in the previous month. Each month, it generates a list of people who reported an accident that required the collection of additional information (circumstances, injury) in a telephone interview.
The TIS can operate multiple independent processes in order to telephone and interview several respondents simultaneously. For the system to be operational, digitally recorded names of the participants, remarks and questions, the telephone numbers, the individually preferred days of the week and times of the day for the telephone call are stored in a database. A voice recognition unit is used to interpret the answers ('yes' or 'no'). People whose answers are not recognized by the TIS after repeated trials are put through to a help-desk.

Method

The TIS was used in two follow-up studies among community-dwelling older people; the 'Safety observed study' (Study 1; n=1055; 15 months follow-up)[5] and the 'Safety in your own hands study' (Study 2; n=2080; 20 months follow-up).[6] Before the start of accident registration, all participants received written instructions about the TIS phone call and the accidents/falls that should be reported. These included home/leisure and traffc accidents regardless of whether or not injury was sustained. During the registration period, the system started at 10.00 hours until 20.00 hours. If participants were not at home, the TIS automatically called again the next day. When a person was contacted, a short introduction was given by a digitally recorded voice, followed by the questions given in table 1. First, the TIS identified the participant, or the person answering the telephone was asked instead. If an accident was reported, within 3 days a computer-aided personal telephone interview was taken. If no accident was reported, the TIS called again the next month.

Table 1 *The digitally recorded introduction and questions that were asked in the 'Safety observed' study by the telephone inquiry system during the dialogue with the respondents.*

Introduction	Good morning/afternoon/evening, you are speaking with the accident registration system of the Leiden 'Safety Observed' study. I call you every month to ask whether [name of the respondent] was involved in an accident at home, in the traffic or elsewhere. You can answer the questions with the words 'yes' or 'no' after the sound signal. I will ask you the following questions: → Id
Id	Am I speaking to [name of the respondent]? 'Yes' → Acc 'No' → Wp
Acc	Have you had an accident that did or did not result in an injury in the past month? 'Yes' → We will call you back to ask about the circumstances 'No' → We call you next month again
Wp	Can [name of the respondent] come to the telephone within 1.5 min? 'Yes' → Would you please ask [name of respondent] to come to the telephone → Id 'No' → Ins
Ins	Can you answer the question instead of [name of the respondent]? 'Yes' → Acc 'No' → We will call [name of respondent] again another time

Table 2 *Indicators of feasibility and reliability of the application of the telephony inquiry system (TIS) in two follow-up studies.*

Feasibility indicators	**Safety Observed Study[5]**	**Safety in your own hands study[6]**
Number of invited persons	3,500	8,650
Participation in follow-up (%)	30.1	24.0
Number of trials with TIS to contact respondents	15,120	33,846
Successful automatic dialogues with TIS (%)	76.9	72.8
Reliability indicators		
Total number of registered accidents	845	968
Accidents in and around home (%)	61.0	60.0
Total number of falls	361	432
Falls requiring medical attention (%)	25.0	25.2
Falls resulting in fracture (%)	3.3	5.1

Results

The results of the follow-up studies are presented in table 2 to illustrate the feasibility and reliability of the TIS. Of the people asked to participate in the follow-up studies, 30.1% (Study I) and 24.0% (Study II) complied. In total, the TIS made 48,966 attempts to have a dialogue with respondents, and 76.9% of these dialogues were successful in Study I and 72.8% in Study II. About 20% of the calls were put through to the help desk. In about 5% no contact was made because persons were not at home at the times of the calls. In each of the studies the compliance of the participants was comparable, on average about 1% dropped out of the cohort each month; in about 30% of the drop-out the use of the TIS dialogue was mentioned as a reason. Although no systematic analysis of specific reasons was possible due to the demands of the medical ethics committee, the most often mentioned problems were: repeated recognition failure by the TIS; and persons reporting they could not hear the telephone voice properly.

In Study I, 61.0% of the 845 reported accidents happened in and around the home and in Study II, 60.0% of the 968 accidents. In Study I, 25.0% of the 361 falls reported required medical attention (hospital, general practitioner, physiotherapist, dentist) and 3.3% resulted in fractures. In Study II, 25.2% of the 432 falls reported required medical attention and 5.1% resulted in a fracture.

Discussion

The technical features of the TIS made it possible to have contact with about 95% of the participants each month. Once the specific application has been built, it can be run automatically several times at relatively low costs, although the help-desk interviewers are needed. As an indication, the current operational costs are estimated to be approximately €5000 (set-up cost) and €500 per 1000 persons per month, including telephone costs, the help desk service and accident interviews.

A structural property of the TIS is that the dialogues are fully structured and therefore identical for all participants, which minimizes interviewer bias.

Although older people may have been unwilling to 'talk' with a computer, the participation in both studies was comparable to that (30%) reported by Hornbrook et al[2]. More than 72% of the 48,966 TIS telephone calls were answered successfully, indicating that respondents could cope with the system. The help-desk facility is regarded as important for the compliance of the participants, because it gave individual support and feedback to those persons who experienced a problem. Because the voice recognition technology is innovating rapidly, recognizing answers will be further improved.

The distribution of accidents in and around the home and outside the home was compatible in both studies, as was the proportion of falls requiring medical attention or resulting in fractures. The proportion of fractures was comparable to those found in community studies involving registration by personal telephoning (2.5%)[1] and registration by mailing fall reports (5.1%).[2] These findings indicate a fair reliability of the TIS. It is concluded that the TIS is feasible in terms of patient willingness and ability to use the system, and that enough indications exist about the reliability of the system for registering accidents and falls among community-dwelling elderly individuals. The relatively low cost of the TIS makes its further use and development viable.

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Chapter 3

Effect evaluation of a multifactor community intervention to reduce falls among older persons

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Abstract

Study Objective
To evaluate the effectiveness of a multifactor and multimethod community intervention program to reduce falls among older persons by at least 20%.

Design
In a pretest–posttest design, self-reported falls were registered for 10 months in the intervention community and two control communities. After the pretest registration, participants followed the intervention program for 14 months. The program included: Information and education, Training and exercise and Environmental modifications.

Setting
All communities were situated in the Province of Friesland in the north of the Netherlands. The study ran from November 1999 to November 2002.

Participants
The participants (intervention: 1122; control: 630) were aged 65 and older and lived independently in the community.

Main Results
There was only a significant decrease exceeding 20% in falls outside the home, among women (OR=.54, 95%CI= .30-.98; p=.041).

Conclusions
The multifactor intervention program did not decrease falls with 20%; only falls outside the home among women were reduced.

Introduction

One in three people aged 65 or older living in the community fall at least once a year.[1-3] While most of these falls do not result in serious injury that requires medical attention, they can affect quality of life because people are frightened of falling again and tend to restrict their activities.[4] On a national level, however, falls have serious implications for healthcare resources. In The Netherlands, with 2.2 million older adults aged 65 and older, the annual direct medical costs of falls amount to about 370 million Euro.[5] As the population ages, these costs will increase if no effective prevention programs are developed and implemented.

As a general proposition, it can be stated that at the time of a fall, one or more risk factors contributed to a situation in which the person, without intention, lost control over his or her body posture due to lack of capability to resist external forces (demands).[6] Multiple factors associated with health, environment, and behavior (physical activity) influence the balance between demands and capability, and for this reason a multifactorial intervention approach would seem the most promising approach to preventing falls.[7-9] Interventions that appeared effective, targeted the people at risk (for instance, people aged 75 and older[10]) and included exercises to increase mobility, strategies to reduce use of psychotropic medication, and home assessment and modification.[8] These elements were included in the design of the multifactorial community-based intervention program called: 'Safety in your own hands' for people aged 65 and older that was implemented in the town of Sneek in the Netherlands.[11] The effectiveness, the reduction of falls or the number of persons who fell down, was evaluated in the study.

Only a few studies have evaluated the effectiveness of interventions in preventing falls in a community-based approach.[12-14] All these studies used hospital data to evaluate the interventions;[12] additionally used self-report information. The studies yielded mixed results. Poulstrup et al.[13] reported a decrease in fall-related lower extremity fractures among women but not among men. Ytterstad[14] found a decrease in fall-related fractures occurring at home among women, and a decrease in fall-related fractures outside the home among men in traffic areas. Kempton et al.[12] found a non-significant 22% decrease in self-reported falls and a significant ($p<.001$) 20% lower fall-related hospitalization rate among both men and women. Based on these findings, the Area Health Authority Fryslân, who initiated the program, aimed to achieve a 20% reduction in falls or persons who fell down inside and outside the home. The effectiveness of the intervention was evaluated in a community intervention trial[15] performed from 1999 to 2002, involving the intervention community (Sneek) and two control communities.

Methods

Subjects and setting

All inhabitants aged 65 and older living independently in Sneek were the target group for the intervention (n=4,369). They were invited to participate in the study. Two control communities (Harlingen, Heerenveen) were suggested by the Area Health Authority Fryslân based on their knowledge of general characteristics. Both control communities were located about 25 kilometers from the intervention community. The total number of inhabitants ranges from 16,000 (Harlingen), 33,000 (Sneek) to 40,000 (Heerenveen); the proportion of persons aged 65 years and over ranges from 13% (Sneek) to 15% (Harlingen, Heerenveen). The average number of inhabitants in the intervention and control communities is about 1000 per km^2. Per 10,000 inhabitants, 5 general practitioners are available in each community.

Study design and procedure

In a pretest–posttest design, self-reported falls were registered in the intervention and control communities for 10 months. In Sneek all 4,369 persons (41.5% male) aged 65 years and over and living independently received a questionnaire and were asked to participate in the study. The same questionnaire was send to 4381 persons in the control communities in the same age category (40.6% male) and living independently. They were randomly selected from the civilian's registry office and asked to participate.

The pretest registration procedure started in November 1999. All participants received a brief written instruction about how to answer a monthly phone call. Subsequently, they were telephoned each month for 10 months and asked, by the Telephone Inquiry System (TIS), an interactive voice response computer, whether they had fallen in the previous month.[16] Those who reported a fall were subsequently telephoned personally and were interviewed about the circumstances and consequences of the falls.

After the pretest registration period, a 14 months preventive intervention program was implemented in Sneek. The posttest registration started after the 14 months intervention period and took 10 months.

Measurements

Outcome variables were the fall incidence and number of people who fell down at least once per 1000 persons per year (the period prevalence of fallers), categorized by sex and location of the fall (inside, outside the home). The results are presented for men and women separately because of the sex-related differences in falls in other studies. The location of the fall (inside, outside the home) was investigated because of the mixed results reported by Ytterstad (1996)[14]. Both measures were used in previous studies on falls[2, 7, 17].

The questionnaire administered at baseline included questions about demographic characteristics: sex, age, marital status (married, divorced, widowed, never married), education (primary, secondary, higher), number of people in the household, type of house (all rooms on the same floor, rooms on different floors). Health-related questions were also included, namely, subjective evaluation of general health (fair, moderate, bad), chronic diseases, and medication use (yes, no). Disability was measured with the OECD disability indicator[18]. Respondents were also asked about the frequency of fear of falling inside and outside the home (never, seldom, regular), use of walking aids inside and outside the home (walking stick, walking frame, rollator, wheelchair, electric medical scooter). Lastly, in order to estimate the level of outdoor physical activity, respondents were asked about the frequency of walking and bicycling during summer and winter (daily, once/twice a week, once/twice a month, seldom or never)[11].

In the personal telephone interviews, information was obtained about the location of the fall (in the home, outside the home). The procedure and measurements were approved by the TNO Medical Ethics Testing Committee in Leiden.

Intervention and control conditions

The intervention was developed and implemented by private and public health and welfare organizations in the Province of Friesland and in Sneek. A steering committee was chaired by the Area Health Authority Fryslân. The intervention included different activities: Information and education; Training and exercise of older persons, volunteers and homecare professionals; and Environment modifications, as presented in table 1. Some aspects of the intervention focused directly and indirectly (through professionals) on a specific group of individuals at risk of falls, namely, people older than 75 years and living independently. Topics of relevance to fall prevention were home assessment and modification, mobility training, and psychotropic medication reduction, as recommended by Gillespie et al. (2003)[8]. Traffic safety, especially related to bicycling, was included because many older people ride a bicycle in the Netherlands and falls from bicycles are common[11].

Table 1 *Description of the intervention activities*

Topic	Aim	Target groups	Mode (s)	Exposure
Information and Education (IAE)				
Aim, content and scope of the project	Raising general awareness of project	All older people, their relatives and professionals working with older people, e.g.: General Practitioners, Pharmacists, Hospital, Library, Physiotherapists, Homecare .	Information market. Leaflets, poster, fall risk profile. Newspapers, Journals Exposition fall prevention	Once; 450 visitors Permanent 32 publications 5 months
		Older people as members of clubs, and other organizations. Medical staff of hospital and GP's.	Presentation at regular meetings Clinical lesson	13 presentations; 300 visitors Once; 30 Specialists, 20 GP's
Home safety	Raising awareness of risks in the home	All older people	Checklist home safety Newspaper articles	Permanent available 4 articles
	Identifying risk factors in the home and offering solutions	Older people 75+	Home visits by trained safety consultants	200 visits
Physical activity	Informing people about importance of mobility training	All older people	Leaflets Course Newspaper articles	 4 courses; 171 participants 7 articles
Medication	Informing people about risks of sleeping pills and tranquilizers	All older people	Leaflets presented at 12 offices of general practitioners and pharmacists. Newspaper articles	12 x 50 = 600 leaflets 3 articles
Traffic safety	Improving knowledge about traffic rules and safety	Older people involved in traffic	Course Newspaper articles	6 courses; 227 participants 5 articles
	Bicycle safety	Older people that ride bikes	Newspaper articles	7 articles
Training and exercise				
Home safety	Identifying risks in the home environment	Professionals working in the home care	Training course	Once; 160 participants
		Volunteers from peer group of older people performing home visits	Training course	Once; 15 participants
Balance training	Prevention of falls	All older people	Training course: In balance, based on Tai Chi Training course: Ageing Well and Healthily	31 participants 20 particpants
Traffic safety	Improving biking skills	Older people that ride bikes	'Biking day'	150 visitors, 35 biking participants
Environmental modifications				
Home safety	Modifying the home environment	Older people asking for assistance	Team of technicians offering assistance	15 requests
Safe pavements in the community	Removing obstacles from pavements	All older people	Telephonic reporting desk for obstacles on pavements	5 working days a week

The aim of the information and educational activities was to raise general awareness of the project and of the risk of falls among older people and professionals working with older people in the community. Specific events were organized (such as an information meeting, presentations at meetings of local organizations, clinical lesson), leaflets and posters were developed, articles were published in local newspapers and magazines, and there was a mobile exhibition about fall prevention. A fall risk profile was developed on the basis of 11 relevant risk factors from the literature.[19] This helped to make people aware of their fall risk. Information about home assessment and modification was provided by means of a leaflet containing a checklist specially designed for use by older individuals. In addition, 15 volunteer safety consultants, who were themselves older individuals, were trained to visit people at risk (aged 75 and older) in their homes, to assess the safety of the home and to mention potential safety issues. They also discussed medication use and the importance of physical activity, mentioning the possibility to attend mobility training. Leaflets on the benefit of physical activity and mobility training for fall prevention, the risk of falls in association with the use of sleeping pills and tranquilizers, and about traffic rules were distributed through healthcare and welfare offices. A technical team was available to help people make necessary changes in the home. They received 15 requests for help. In addition, a telephone desk for complaints about pavements was run by the Department of Public Works, which undertook to address any such reports.

Two 'In balance' mobility-training courses were given to 31 participants. People were told about the risk of falls and performed exercises (based on Tai Chi principles). Also the course 'Ageing Well and Healthily'[20] was given twice that included information and mobility training. With regard to traffic safety, a biking day was organized during which the participants' bicycles were given a safety check and then participants went for a bicycle ride. In total, 800 individuals, among whom 50 healthcare professionals and 160 homecare professionals attended one or more meetings, 10 courses were organized (attended by 398 people) and 22 articles were published in local magazines and newspapers.

In the control communities no falls prevention programs were running during the study. The Area Health Authority Fryslân, that covers the area of the intervention as well as the control communities, monitored prevention initiatives related to older persons. During the study period in the control communities the conditions related to falls prevention were not changed due to local preventive initiatives. Publications about falls prevention in the intervention community were not published in newspapers in the control communities.

Study Power

Power analysis (alpha=.05 (one tailed), 1-Beta=.80) indicated that there should be 1800 participants in the intervention and control communities. On the basis of another community study,[21] we estimated that, during a 10-month period, 10% of the participants would fall and that 20% would drop out during the study period (pretest and posttest). Also the aim of the intervention, 20% reduction, was taken into account.

Statistical Analyses

Data for respondents who participated at least 1 month in both the pretest and posttest periods were analyzed, using SPSS 10.0 for Windows. A general outdoor physical activity score was computed. For each individual, the reported outdoor physical activity (walking, bicycling in summer, winter) in the categories: each day=4, once or twice a week=3, once or twice a month=2, seldom or never=1, were summed to generate 13 outdoor physical activity levels. The highest score (16) reflects the highest outdoor physical activity. Outdoor physical activity was then categorized in three tertiles: inactive (4-10), moderately active (11-14), and active (15-16). Descriptive statistics were used to describe the main characteristics of the respondents in the intervention and control communities. The groups were compared using t-tests (for numeric data) and chi-square test. To analyze the effectiveness of the intervention, weighted difference scores were calculated based on the number of months a respondent participated. For further analysis and testing Logistic regression (period prevalence of fallers) and Analysis of Variance (incidence of falls) were used. Differences in main characteristics of participants in the intervention and control communities at baseline were taken into account by including these variables in the analysis models.

Results

Inclusion and drop out of subjects in the study

Of the 4369 people sent a questionnaire in the intervention community, 1338 (30.6%) were included in the study; in the control communities 16.9% (n=742) were included. Two hundred-sixteen people (16%) from the intervention community and 112 people from the control communities (15%) dropped out during the study. More men than women and relatively older people (80+) dropped out, but at a comparable rate in both communities. Thus, data for 1122 people from the intervention community and 630 people from the control communities were available for analysis (figure 1). With these group sample sizes we can achieve 80% power to detect a 28% reduction of the period prevalence of fallers.

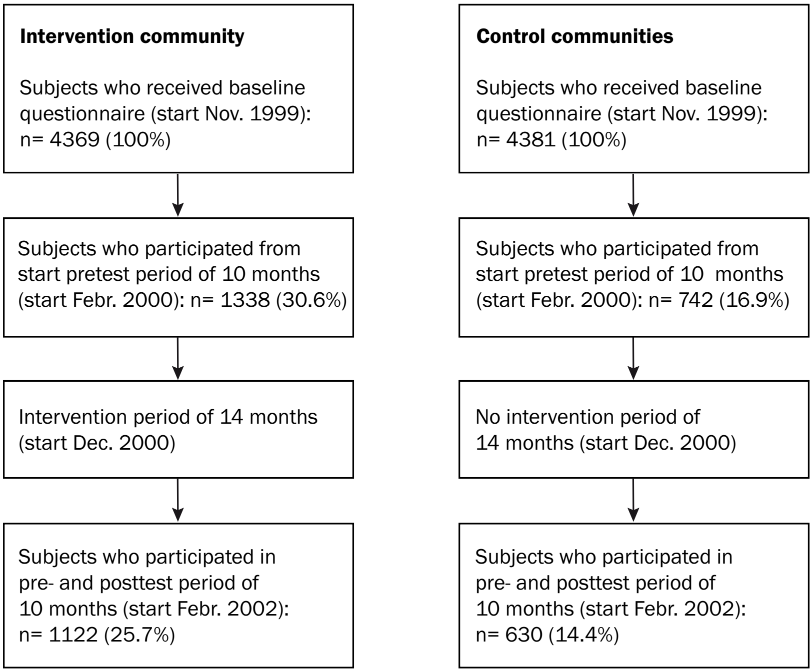

Figure 1 *Flow chart of inclusion and participation of subjects in the study*

Characteristics of subjects in the study

The main characteristics of the study participants at baseline are given in table 2. People from the control communities had, relative to the intervention group, a higher level of educational attainment, lived more often in houses with two or more floors, experienced more difficulty with transfer from chair and less often reported dizziness with falls as a health problem in the past year. The intervention community appeared to be more physical active outside the home. However, the difference was only significant for women (chi=6.1 (df=2), p=.047) and not for men (chi=2.5 (df=2), p=.282).

Table 2 *Demographic, health, and disability variables of the people included in the analysis from the intervention and control communities*

Variable	Categories	Intervention Community	Control Communities	Test statistic, P Value
N		1122	630	
Age (years)		72.6	72.9	ns*
Female		59.0%	55.8%	ns
Living alone		34.5%	32.2%	ns
Education	Primary Secondary Higher	36.0% 52.6% 11.4%	28.8% 57.4% 13.8%	chi= 9.6 (df=2), p=.008
Living situation	One floor	37.3%	26.8%	chi= 19.6 (df=1), p<.001
Subjective health	(Very) good	68.0%	65.2%	ns
Dizziness with falls	Yes	7.6%	4.5%	chi= 5.7 (df=1), p=.017
Regular fear of falling	Inside the home Outside the home	16.7% 22.6%	15.6% 20.6%	ns ns
Disability (Yes)	Face recognition at 4 meters	11.0%	10.1%	ns
	Carrying object of 5 kilograms for 10 meters	36.6%	36.1%	ns
	Bending	31.4%	32.5%	ns
	Walking 400 meters	24.3%	27.7%	ns
	Dressing	6.3%	9.0%	ns
	Transfer from bed	6.1%	6.9%	ns
	Transfer from chair	9.7%	12.8%	chi= 4.0 (df=1), p=.046
	Stair climbing	25.6%	29.1%	ns
	Performing demanding household activities	45.2%	46.6%	ns
Use of any walking aid	In the home Outside the home	15.9% 19.2%	17.8% 23.0%	ns ns
Outdoor physical activity level (walking, bicycling)	Active Moderately active Inactive	29.9% 37.6% 32.5%	25.0% 36.7% 38.3%	chi=7.1 (df=2), p=.028

*ns= non-significant two sided test p>.050

Pretest registration of falls in the community

Pretest, the weighted period prevalence of fallers was 145 in the intervention community (some persons were involved in falls in and around, as well as outside the home) and 134 in the control communities. The related weighted incidence rate of falls was 226.3 and 203.9 for the intervention and control communities, respectively (table 3).

Table 3 *Weighted number of people involved in at least one fall (period prevalence of fallers) and number of falls per 1000 persons per year by sex and domain of falls for the intervention and control communities by pretest and posttest registration periods*

Type of accident		Intervention community		Control communities		Test result*
Falls in and around the home		Pretest	Posttest	Pretest	Posttest	
Persons involved per 1000 persons per year (N):	Men	87.5 (32)	80.1 (25)	80.3 (17)	76.0 (16)	p=.851
	Women	110.7 (54)	136.0 (65)	122.8 (31)	108.0 (27)	p=.346
	All	101.3 (86)	113.7 (90)	104.3 (48)	94.1 (43)	p=.443
Incidence of falls per 1000 persons per year (N):	Men	140.7 (39)	95.4 (27)	143.7 (18)	99.9 (18)	p=.680
	Women	171.9 (67)	175.0 (72)	170.4 (33)	158.6 (36)	p=.972
	All	159.3 (106)	142.9 (99)	158.8 (51)	133.1 (54)	p=.892
Falls outside the home						
Persons involved per 1000 persons per year (N):	Men	34.8 (12)	63.3 (21)	31.2 (6)	52.9 (11)	p=.278
	Women**	59.1 (29)	65.1 (32)	28.0 (7)	103.4 (27)	p=.041
	All	49.2 (41)	64.3 (53)	29.4 (13)	81.5 (38)	p=.279
Incidence of falls per 1000 persons per year (N):	Men	52.3 (13)	93.6 (23)	43.7 (6)	68.4 (12)	p=.303
	Women	76.9 (30)	81.3 (35)	46.2 (8)	114.4 (28)	p=.111
	All	67.0 (43)	86.3 (58)	45.1 (14)	94.4 (40)	p=.663

* Logistic regression for persons involved, analysis of variance for incidence, corrected for education, living situation, diziness with falls, transfer from chair and outdoor physical activity level (walking, bicycling)
** OR=0.54, 95% CI= (.30-.98)

Falls and outdoor physical activity at baseline

At baseline, the weighted period prevalence of fallers for Men, Women and All, did not differ significantly between the intervention and control communities; neither for falls in and around the home nor for falls outside the home (chi-square tests with all $p > .050$), and when corrected for education, living situation, dizziness with falls, transfer from chair and outdoor physical activity level (walking, bicycling) with all $p > .050$.

The level of outdoor physical activity appeared to be positively related to the period prevalence of fallers outside the home and negatively related to the period prevalence of fallers inside the home at pretest as shown in table 4.

Table 4 *Period prevalence of fallers inside the home and outside the home by level of outdoor physical activity*

Outdoor physical activity (walking and bicycling)				Test result
Period prevalence of fallers*	**Inactive**	**Moderately active**	**Active**	**Logistic regression**
Inside the home	125.1	108.9	64.2	OR= .72 95% CI= .57- .91, p= .007
Outside the home	23.5	54.6	52.4	OR= 1.44 95% CI= 1.02- 2.03, p= .039

* per 1000 persons per year

Effectiveness of the intervention

For analysis, the pretest and posttest results were adjusted for significant differences in characteristics at baseline of the persons between experimental and control communities as presented in table 2.

The intervention did not significantly reduce the period prevalence of fallers or the number of falls per 1000 persons per year relative to control. However, there was a significant relative reduction exceeding 20% in the period prevalence of fallers outside the home, and especially among women (OR=.54, 95%CI=.30-.98; p=.041). The relative reduction was mainly due to a strong, about three to fourfold, increase in the period prevalence of women who fell in the control communities in the post intervention period. In contrast, the period prevalence of women in the intervention community who fell was not different before or after the intervention.

No relation was found between the increase in age of the participants and the increase in the incidence of falls between the pre- and posttest periods (OR=1.01, 95% CI= .97- 1.04; p>.050).

Discussion and conclusions

Persons aged 65 years and older, living independently in the community, took part in a multifactorial and multimethod community-based intervention aimed to achieve a 20% relative reduction in the period prevalence of fallers and in the number of falls. The results show that the aim of the intervention was not achieved; therefore the intervention is not regarded as effective.

The intervention included information and education, training and exercise and environmental modifications related to home safety, physical activity, medication use, and traffic safety. It included therefore the combination of intervention elements that were effective in reducing falls in other studies.[8] However, in practice only few people took part in balance training and few requests for assistance with modifying the home were received (table 1). The best received aspects of the intervention were those concerning Information and Education activities aimed at raising awareness of the risk of falling among older people and professionals and related risk factors like medication use. For this reason, the main impact of the intervention was on these aspects. The lack of participation in advised interventions that we found is recently studied by Yardley et al.[22] They conclude that falls prevention advice among older persons was typically regarded as useful in principle, but not personally relevant or appropriate. Advice about falling was often depicted as common sense, only necessary for older or more disabled individuals, and potentially patronizing and distressing. Therefore the willingness to participate actively in preventive interventions is generally low. Yardley et al.[22] suggest that messages that focus on the positive benefits of improving balance may be more acceptable and effective than advice on falls prevention.

For the effect evaluation of the intervention, a pretest–posttest design was chosen to correct for a possible 'natural' variation in fall incidence between the pretest and posttest period, for instance due to aging of the persons involved in the study or seasonal variation.

Although the aim of the intervention was not achieved, the effect evaluation shows a selective relative reduction in falls outside the home among women only. While the period prevalence of fallers did not increase for women from the intervention community, it did for women of the control communities. Although not statistically significant, among men in the intervention as well as the control communities, a tendency towards an increase in outdoor falls is also observed, indicating a general trend towards increased outdoor falls in the post intervention period.

Due to lack of data related to the post intervention period, we can not explain from our study why the relative reduction of the period prevalence of fallers, especially among women, is observed.

However, a selective reduction in falls for women in community-based intervention studies was also reported by other authors.[13,14] On the basis of hospital data, these studies reported a reduction in fracture rates due to falls among women only. The authors suggested that women may be more receptive than men to a fall prevention intervention. Other studies suggest a mechanism that might help to explain of our findings, although more research is needed to be conclusive about its appropriateness. Schoenfelder et al.[23] found that information about risk factors for falls raised risk awareness and concern about falling among women in particular. It has been suggested that people who are worried about falling limit their activities, especially outside the home, to reduce the fall risk.[24-26] In their studies, Kempton et al.[12] and Hahn et al.[27] explained the reduction in physical activity as being due to people following the often-given advice to 'take it easy' when they raise the issue of falling among relatives and their doctors.

The phenomenon that persons reduce physical activity (reduce demands) as a behavioral response to increased perceived task difficulty (due to information about risk factors for, and possible consequences of falls) is in agreement with the task difficulty homeostasis theory.[28] This theory describes the behavioral response of persons in order to balance perceived demands and capabilities in order to prevent loss of control (in this context the loss of control of body posture). This mechanism may have reduced the participation in outdoor activities by older women in the intervention community, because they were most sensitive to the information about the risk of falling.

Based on crossectional data in our study, a relative low level of participation in outdoor physical activity appeared to be associated with reduced outdoor falls. However, at the same time a relative low level of outdoor physical activity was associated with an increased involvement in falls in and around the home; for instance because the persons spend more time at home. These associations may in part indicate why outdoor falls were reduced, while falls in the home did not decrease among women after the intervention.
An important limitation of the study is that participants were not randomly allocated to an intervention or control group. The community approach that was applied did not leave the opportunity for individual randomization because many interventions were presented to all older inhabitants of the intervention community. The selected design, including the two control communities, leaves open the possibility of unknown confounders that influence the results. By taking into account all differences in baseline characteristics of persons in the intervention and control communities during the analysis, the influence of confounding was reduced. A weakness related to this issue is that we did not measure changes in factors that are related to accident risk, such as the level of physical activity of the participants. The main reason for this omission is that the funding of the study was not sufficient for including these measurements. As a result, we are not able to explain the increase in the period prevalence of fallers outside the home in terms of changes in exposure to specific risk factors for different groups. Increased age (participants were about 2 years older

in the posttest period) was not associated with the increased incidence of falls. It remains to be established more decisive to what extend the assumed decrease in outdoor physical activities is a consequence of information and education about the risk of falls. Future studies should therefore measure changes in the level of physical activity of participants.

Another weakness of our study is the high drop-out rate, which reduced the power of the study. The high drop-out rate could be the consequence of the long follow-up period, about 3 years with a break of 14 months, and the old age of the participants. However, despite the drop out, at baseline both intervention and control communities did only differ significantly on a limited number of respondent characteristics. For these differences was controlled during analysis.

The results showed that the multifactorial intervention was not effective to achieve the 20% falls reduction and only reduced the period prevalence of fallers outside the home among women. It is suggested that the mechanism involved is that these women reduced their outdoor physical activity compared to the other persons involved in the study. Future follow-up studies should assess to what extent people change their level of physical activity both in and outside the home as a result of prevention interventions. These data can provide insight into the way older people modulate the balance between task demands and performance capability in order to cope with their perceived risk of falling.

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Chapter 4

The 24-hour distribution of falls and person-hours of physical activity in the home are strongly associated among community dwelling older persons

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Abstract

Objectives
Most research on falls among older persons focuses on health-related factors that affect the ability to maintain balance. The objective of the study is to determine the association between physical activity and occurrence of falls among community-dwelling older persons.

Methods
The distribution of falls and person-hours of physical activity in the home over 24 hours was compared. The falls data (n= 501) were extracted from a pooled dataset of three follow-up studies conducted between 1994 and 2005 (n=3587). The 1995 Dutch National Time-Budget Survey provided hour by hour information on activities performed by older individuals (n=459) in the home; this sample was representative for the Netherlands. The association between the 24-hour distribution of falls and physical activity and the risk of falling (the ratio between the distribution of falls and physical activity) were determined. Participants were community dwelling older persons aged 65 years and older.

Results
More physical activity was positively associated with more falls (Spearman correlation=.89, p<.000). The risk of falling at night (1 a.m. to 6 a.m.) was almost eight times higher compared to 7 a.m. to 12 p.m.

Conclusions
Physical activity is strongly associated with the number of falls in the home, measured over 24 hours. Older persons may be at increased risk of falling if they are encouraged to become more physically active, or if they often get out of bed at night. Thus in addition to health-related factors, also changes in level of physical activity should be taken into account when estimating a person's risk of falling.

Introduction

Each year about 30% of all community dwelling older persons fall at least once[1] and about 5% of these falls result in a hip fracture. The consequences of falls and hip fractures are serious, including 20% mortality 1 year after a hip fracture[2] and significant disability and reduced quality of life.[3,4] A fall is frequently defined as 'An unexpected event in which the participants come to rest on the ground, floor or lower level'.[5] In general, a person will not fall if his/her capability to control his/her balance is greater than the demands put on it,[6] which suggests that the risk of falling is determined by the capability to maintain balance and by the demands made on a person to maintain his/her balance. For example, a person with severe mobility problems may have a high risk of falling if he/she has to climb the stairs five times a day but a lower risk if he/she has to climb the stairs only once a day. Although Skelton[7] addressed the relevance of the level of physical activity as a demand factor for balance control, current research on risk factors for falling is mainly focused on health factors that are related to a person's capability to control balance.[1,8] While there is evidence that high demands made on the locomotor system, such as occur during walking[9-11] physical exercise[11,12] or walking and cycling,[6] are associated with an increased risk of falling, little is known about the association between variations in physical activity and falls, independent of variations in the capability to maintain balance. We hypothesized that at time periods during the day with relatively high levels (person-hours) of physical activity in the home, the frequency of falls among older persons is also relatively high.

Methods

We analyzed the distribution of physical activity over 24 hours on the assumption that a person's capability to control balance is fairly constant throughout this time period. We pooled the 24-hours physical activity distributions of all subjects; those who are generally active or inactive.

We limited the study to falls in the home because falls outside the home are more complex, being influenced, for example, by traffic and weather conditions. We investigated whether daily changes in physical activity in the home are associated with the frequency of falls among community dwelling persons aged 65 years and older. To this end, we analyzed pooled data from three follow-up studies of falls among community dwelling elderly persons, and from a database of the Dutch National Time-Budget Survey (TBO).[13]

The three follow-up studies of falls used comparable research procedures 14 and were conducted between 1994 and 2005 (pooled n=3587); the follow-up ranged between 10 and 15 months. A questionnaire was used to measure general subject characteristics at baseline (e.g.: age, gender, subjective health (good, moderate/ bad)), and an interactive voice response computer was used to register falls monthly.[14] The characteristics of the reported falls (e.g.: time of the day and location of the fall) were obtained by telephone interview within a week after respondents reported a fall.
The 1995 Dutch National Time-Budget Survey provides information on how much time the Dutch population older than 12 years spends on (and on which) household activities, labor activities, and leisure-time activities in an average week. The data are representative for the Dutch population. Data were collected every 15 minutes for the main activity (see table 1) performed inside or outside the home for on average 1 week.

Table 1 *Main categories of activities included in the Dutch Time-Budget Survey (1995)*

Activities included in the Dutch national Time-budget survey	
Main categories N=10	**Illustration**
Professional work	At home, outside the home, transportation to/ from/ during work
Household work	Preparing meals, cleaning windows or floors, doing the laundry
Care for children	Baby-sitting, reading aloud, playing games
Shopping	Shopping, going to the post office and bank, obtaining medical care,
Personal needs	Sleeping, medical care at home, caring for others at home, personal hygiene
Attending school, courses	Attending lessons, doing homework
Religious, political activities	Attending meetings, supporting other persons
Leisure, social and cultural activities	Attending sports/ music performance, visiting museum/ restaurant/ friends
Sports and active leisure time activities	Sports participation, walking, bicycling, making music, doing handicrafts
Listening to radio, watching tv, use of computer, reading, talking	Telephoning, reading books/ newspaper, writing letters/ postcards

Subjects

We analyzed the data of 501 persons who had reported one or more falls in the home and the actual time when the fall occurred, and collected physical activity data for persons older than 65 years from the National Time-Budget Survey (N=459). Some characteristics of the included subjects are presented in table 2. It appeared that the distributions of gender, age and subjective health differed significantly between both datasets.

Table 2 *Characteristics of subjects who fell in the home (pooled Dutch data from three studies in Leiden, Sneek, Harlingen, Heerenveen, Smallingerland between 1994 and 2005) and subjects involved in the Dutch Time-Budget Survey (1995)*

		Persons involved in a fall at home N=501		**Persons involved in Time-Budget Survey N=459**		**Chi-Square test (2-sided)**
		N	%	N	%	
Gender	Men	163	32.5	191	41.7	Chi=8.6,df=1, p=.003
	Women	338	67.5	268	58.3	
Age	65-69 years	111	22.2	226	49.2	Chi=130.8,df=3, p<.000
	70-74 years	134	26.7	144	31.3	
	75-79 years	119	23.8	63	13.8	
	80+ years	137	27.3	26	5.6	
Subjective health	Good	133	55.9	331	73.2	Chi=21.3,df=1, p<.000
	Moderate/bad	105	44.1	121	26.8	
	Missing	263		7		

Data Analysis

If a person fell multiple times in the home, we selected one fall at random for the analysis. We used SPSS to generate the random selection.

Falls were classified by the time of the day they occurred (in 2-hour time bands). Data from the Time-Budget Survey were recoded according to whether people were physically active (e.g.: walking, climbing, standing) or inactive (e.g.: sitting, lying). Examples of activities that were coded as physically active are preparing meals, cleaning the house, and doing the washing. Activities that were regarded as inactive were reading, sleeping, and watching television. The distribution of physical activity over 24 hours was calculated by adding, for each 2-hour period, all 15-minute physical activity scores for activities in the home for all the subjects. The physical activity scores for each 2-hour period over 24 hours were summed for all days of the week, yielding the number of person-hours of physical activity in the home per 2-hour period. Since the data on falls and the physical activity score were obtained from separate databases, we used the direct standardization method[15] to increase comparability between the falls distribution and the distribution of physical activity. Data on falls were standardized by age and gender; subjective health was not included because it did not have an additional contribution after age and gender were used. Spearman's rank coefficient was used to assess if the falls distribution was changed due to the standardization procedure. It was assumed that in the time period of 9 a.m. to 4 p.m. persons are more physically active compared to the time period 5 p.m. to 8 a.m. The T-test was used to assess differences between these two time periods in the number of physical active hours and falls. Spearman's rank coefficient was used as a measure of the association between the distribution of falls and physical activity. In addition, we calculated the risk of falling as the ratio between falls and person-hours of physical activity for each 2-hour period.

Results

Before standardization 501 falls were included in the distribution; afterwards the number was reduced to 436. The distributions of falls before and after standardization were highly comparable as indicated by the Spearman rank correlation .99, $p < .000$. The time distribution of the 436 falls is presented in table 3.

Table 3 *Time of day distribution (per 2-hours period and 9 a.m. to 4 p.m. versus 5 p.m. to 8a.m.) of number of falls at home adjusted by age and gender (pooled Dutch data from three studies in Leiden, Sneek, Harlingen, Heerenveen, Smallingerland between 1994 and 2005), the number of physical active person hours (Dutch Time-Budget Survey,1995) and their ratio.*

Time of the day	Falls* at home (N=436) N, (%)	Number of physical active person hours (N=459) N, (%)	Ratio Falls*/ physical active person hours
1-2 a.m.	16 (4)	106.3 (1)	.150
3-4 a.m.	13 (3)	2.5 (0)	5.216
5-6 a.m.	3 (1)	14.5 (0)	.208
7-8 a.m.	16 (4)	856.3 (7)	.019
9-10 a.m.	63 (14)	2837.8 (22)	.022
11-12 a.m.	112 (24)	1990.5 (16)	.056
1-2 p.m.	42 (10)	1772.8 (14)	.024
3-4 p.m.	81 (19)	1173.6 (10)	.069
5-6 p.m.	30 (7)	1573.3 (13)	.019
7-8 p.m.	26 (6)	1213.8 (10)	.021
9-10 p.m.	16 (4)	180.1 (2)	.089
11-12 p.m.	18 (4)	659.3 (5)	.027
	Mean (sd)	Mean (sd)	
9 a.m. to 4 p.m.	74.3 (29.2)	1943.7 (688.9)	.038
5 p.m. to 8 a.m.	17.3 (8.2)	575.7 (598.6)	.030
T-test	t=-3.83,df=3.2,p=.03	t=-3.56,df=10,p=.005	

The frequency of falls differed over 24 hours, with significantly more falls occurring between 9 a.m. and 4 p.m (mean number of falls per two hour period is 74.3; sd=29.2) compared to the period 5 p.m. to 8 a.m. (mean number is 17.3; sd=8.2); (t=-3.83,df=3.2,p=.03).
The level of physical activity was high from 9 a.m. and gradually decreased until about 8 p.m., and was lowest between 9 p.m. to 10 p.m. and between 1 a.m. to 6 a.m. The mean number of physical active person hours per two hour period is significantly higher between 9 a.m. to 4 p.m (mean is 1943.7; sd=688.9) compared to the period between 5 p.m. to 8 a.m. (mean is 575.7; sd=598.6); (t=-3.56,df=10,p=.005). The data are presented in table 3.
The Spearman rank correlation between falls and physical activity over 24 hours was .89, p<.000 (significantly different from zero). The data are presented in table 3.
The risk of falling, calculated as the ratio of falls in the home and level of physical activity during a 2-hour period, was particularly high between 1 a.m. to 6 a.m. (.260) compared to 7 a.m. to 12 p.m. (.033); an almost eight times increase.

Discussion and Conclusions

We found that, over 24 hours, physical activity is strongly associated with the number of falls in the home among community dwelling persons aged 65 years and older. This was first of all indicated by the association between the distributions of the number of falls and the number physical active person hours. The second indication is that within the time period in which the mean number physical active person hours appeared significantly higher (9 a.m. to 4 p.m.), also the mean number of falls was significantly higher.
The findings support indications from other studies showing that some types and patterns of physical activity or exercise are associated with an increased risk of falls.[6,7,9-12] In addition, persons who are physically active at night, for example, getting out of bed, appear to be at high risk of falling. The extreme high value of the ratio at 3 to 4 a.m. (5.2) is based on a relative low number of physically active person-hours and should therefore be interpreted with caution. Therefore this value is not discussed separately form the other ratio's that were found in the time period of 1 to 6 a.m.
In our study, we took the 24 hours distribution of physical activity of individual subjects into account. We pooled these distributions irrespective of the level of physical activity of the subjects. In explorative analyses of our physical activity data, we made separate physical activity distributions for subjects with good and reduced

general health. Although the mean level of physical activity between these groups differed, the distributions of physical activity were not different. This implies that the pooled distribution of physical activity adequately represents the distribution of active and inactive subjects.

A shortcoming of this study is that the data about falls and physical activity came from different populations. However, it would be too demanding for subjects to report falls as well as physical activity at the required level of detail for many months, probably resulting in a high dropout rate. The age and gender standardization procedure we used to match the persons who fell with the population in which physical activity was measured is regarded as an adequate tool to enable comparison of these populations.[15] It appeared that the falls distribution was not affected by this procedure. A limitation of the study is that we only had a small range of variables to match both populations.

The strong association between the level of physical activity and falls among community dwelling older persons might imply that if older persons change their level of physical activity they will modify their risk of falling. For research on risk factors for falling and prevention evaluation studies, this means that if subjects become less physically active, they may mask the impact of certain risk factors for falling. For example, in research on fear of falling, a high fear of falling is associated with physical inactivity and not always with more falls.[6,16] On the other hand, if persons become more physically active, for instance by participating in a physical exercise intervention, the number of falls may not decrease because more demands are made on the individual's capability to control balance. For clinical practice, the findings imply that before patients are encouraged to become more physically active, because of the associated general health benefits,[17] they should be screened, and if necessary treated, for gait and balance problems[1] in order to prevent the risk of falling from increasing. More specifically, the high risk of falling at night requires special attention. In this respect, the prescription of sleeping tablets, which reduce a person's capability to control balance, and diuretics, which might increase the frequency of toilet visits, should be reviewed taking into account their possible impact on night time falls risk. In addition further study is required of specific circumstances and behavioral patterns which might cause the increased falls risk at night.

To conclude, older persons may be at increased risk of falling if they are encouraged to become more physically active, or if they often get out of bed at night. In order to estimate and reduce the risk of falling, clinicians should take not only health-related factors but also, changes in, the level of physical activity into account. Daytime physical activity can be estimated by asking persons how many days a week they are physically active for at least 30 minutes, as recommended by health promotion and disease prevention policy.[8] Night time physical activity can be estimated by asking them how often they get out of bed at night. In future research, the objective assessment of physical activity, such as actigraphy, should be enhanced to validate the recommended self-reported physical activity.

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Chapter 5[a]

Older persons afraid of falling reduce physical activity to prevent outdoor falls

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Prev Med 2007; 44:260-264

Abstract

Objective
The aim of this study was to test the assumption that outdoor physical activity mediates the relationship between fear of falling and actual outdoor falls according to the Task Difficulty Homeostasis Theory.

Method
A prospective follow-up study of 10 months conducted in the year 2000 in three municipalities in the province of Friesland, The Netherlands. The participants were1752 people aged 65 and older, living independently, in the community. Main baseline data were age, sex, outdoor physical activities (walking, bicycling), and fear of outdoor falls. The number of people who fell outdoors was recorded.

Results
People with a high fear of falling were more often low to moderately active or active compared with people who had no such fears and were more often very active. Fear of falling was not associated with outdoor falls, but it was after correction for level of physical activity.

Conclusions
Outdoor physical activity mediates the relationship between fear of falling and actual outdoor falls. This implies that the incidence of falls as an outcome in studies does not adequately represent the impact of risk factors for falls and that level of physical activity should be taken into account.

Introduction

Older individuals often fall down, and about 30 percent of people older than 65 years living in the community fall one or more times a year.[1] Falls[2] and risk factors for falls[3] are associated with the fear of falling, and about 20 to 60 percent of older people living in the community report a fear of falling. Several studies have found fear of falling to be (causally) related with a restriction of physical activity[1,5-9] indicating that people adjust their behavior (i.e., participation in outdoor activities) according to their feelings of risk of falling. It is, however, not known to what extent such restriction of physical activity reduces the actual risk of falling.

The Task Difficulty Homeostasis Theory (TDHT) describes a mechanism where the feeling of risk has consequences for related behavior.[10] Task difficulty is an expression of the gap (safety margin) between task demand, and capability of a person during performance of an activity.[10] Controlling body posture can be regarded as a task that is performed more or less consciously during an activity like for instance gardening.

According to this theory, people compare the experienced task difficulty (to control body posture) with their target level of task difficulty and adjust their behavior in an attempt to eliminate any discrepancies between the two. Fuller[10] found that perceived task difficulty is closely related to feeling of risk, which represents an emotional response to a threat; like fear of falling. Thus people with a relatively strong fear of falling would be expected to restrict their physical activities correspondingly, in order to keep their experienced task difficulty at the 'target level'. A key element of the target level of task difficulty is the upper boundary of difficulty (smallest safety margin) beyond which a person prefers not to go.[10]

In order to test the relevance of the TDHT to falls among people aged 65 and older living in the community, the assumption is tested that outdoor physical activity (bicycling, walking) mediates the relationship between fear of falling and actual outdoor falls[11] according to the TDHT. We expected that fear of falling would not be associated with actual outdoor falls because people would try to reduce their outdoor activities according to their level of fear of falling. However, after taking the level of physical activity into consideration, we expected that fear of falling outdoors would be associated with actual falls outdoors.

Methods

Setting and subjects

The study was conducted in the year 2000 in three communities (Sneek, Harlingen, and Heerenveen) in Friesland, a province in the north of The Netherlands. Potential participants were people aged 65 and older living in their own homes; the names and addresses of 8650 randomly selected potential participants were sent to us by the local registry office and we asked these people by mail to participate in the study. People who gave their written informed consent were included. The Medical Ethics Testing Committee in Leiden approved all procedures.

Design
This prospective follow-up study was part of the 'Safety in your own hands study'.[12] At baseline, participants were asked to complete and return a questionnaire. Then they were telephoned at home once a month, starting at February, for 10 months and asked whether they had fallen in the previous month. The participants were called by means of the Telephone Inquiry System (TIS), an interactive voice response computer that records replies by applying voice recognition technology.[13] All participants (and their partners, important in case of hospitalization) had received written instructions on how to answer this phone call. If persons did not answer the telephone call, the TIS automatically called the next day again until a response was obtained. Those who reported a fall were subsequently telephoned by a person and asked about the circumstances and consequences of their fall.

Assessment
The questionnaire included questions about the following baseline characteristics: sex, age, education (low, intermediate, high), living alone, and perceived general health (fair, moderate, bad). People were also asked how often they were afraid of falling outdoors (never, seldom, regular, very often), and, as indicator of outdoors physical activity, how often they walked outside for at least half an hour and how often they bicycled during the winter and summer (each day, once or twice a week, once or twice a month, seldom, or never).

Outcome measures
During the personal telephone interview, we gathered information about the location of the fall (in the home, outside the home) and the activity (for instance: walking, climbing stairs, transfer from a chair, bicycling). The outcome measure of the study was dichotomous: reporting at least one fall outdoors during walking or bicycling, or reporting no falls outdoors.

Analyses
Analyses were performed in 2005 for this specific aim. The questions about outdoor physical activity were combined to generate a general outdoor physical activity measure. For each individual, the reported activity (walking, bicycling in summer,

winter; note: these activities were chosen because most outdoor falls happened during these activities) in the categories: each day=4, once or twice a week=3, once or twice a month=2, seldom or never=1, were summed to generate 13 outdoor physical activity levels. The highest score (16) reflects the highest outdoor physical activity. Physical activity was then categorized in three tertiles: low to moderately active (less than once a week both activities; 4-10), active (about once or twice a week both activities; 11-14), and very active (about every day both activities; 15-16). Fear of outdoor falls was dichotomized as low (never or seldom has fear of falling) and high (regularly and very often has fear of falling).

Firstly, we carried out a polytomous logistic regression analyses with fear of outdoor falls as independent variable, age and sex as fixed variables, and outdoor physical activity as dependent variable. Odds ratios for outdoor physical activity are presented with reference to the 'very active' category. This analysis was aimed to test the assumed association between fear of falling and the level of physical activity.

Then, three logistic regression analyses were performed according to Baron et al.[11] with fear of falling outside the home as independent variable, outdoor physical activity level as mediator variable, and outdoor falls during walking and bicycling as the dependent variable. Age and sex were included as fixed variables, to take possible confounding effects of these variables into account. SPSS-11 was used for all analyses. A level of .05 was considered to indicate statistical significance in all analyses.

Results

The questionnaire was sent to 8650 people and returned by 2080 (24%) people, all of whom agreed to participate in the study (figure 1). Data for 1752 (84%) people who completed the study were analysed. Drop-out was not selective for sex (42% of the participants were men) but was for age (relatively more older people dropped out). The mean age of the people whose data were analyzed was 73.0 years.

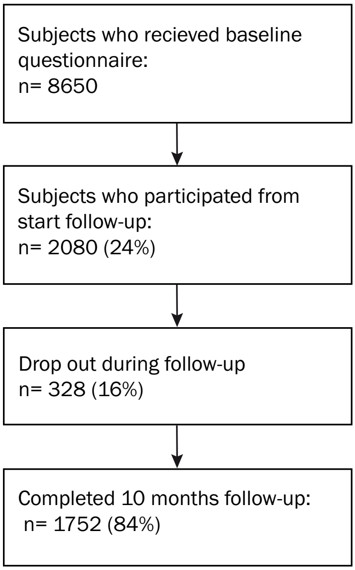

Figure 1 *Flow chart of inclusion and participation of subjects in the study in Friesland, The Netherlands, 2000*

About 22% (n=374) of the older people reported fear of falling outside the home, and 3% (n=52) actually fell down outdoors during walking or bicycling in the 10-month follow-up period (see table 1). The total incidence of fallers per 1000 person-years participation in the follow-up was 141; 102 (72%) inside and 43 (30%) outside the home (some persons fell inside as well as outside the home).
Logistic regression analyses showed that participants with a high level of fear of falling were more often active (OR=1.5; 95% CI=1.1, 2.2; p=.02) or low to moderately active (OR=2.9; 95% CI=2.1, 4.2; p=.00) than those with a low fear of falling (see table 2). Analyses also showed that active and very active individuals fell outdoors more often than people who were 'low to moderately active' (OR=2.8; 95% CI=1.3, 6.3; p=.01) and (OR=2.6; 95% CI=1.1, 6.1, p=.03), respectively (table 3). However, fear of outdoor falls was not significantly correlated with outdoor falls (OR=1.7; 95% CI=.9, 3.2; p=.1) but it was if the level of outdoor physical activity was corrected for in the logistic regression model (OR=2.0; 95% CI=1.1, 3.9; p=.03) (table 4).

Table 1 *Baseline characteristics and outcome measures of the study population (n=1752).*

Baseline characteristics	Value	%
No persons involved in the study	1752	
Age (mean, (SD))	73.0	(5.8)
Female	1011	58
Elementary school education or less	580	33
Living alone	583	34
Fair perceived health (versus moderate and bad)	1155	67
High fear of outdoor falls (versus low fear)	374	22
Activity level related to outdoor walking and bicycling: - Low to moderately active - Active - Very active	 572 633 485	 34 37 29
Outcome measure:Falls		
Persons with at least one outdoor fall (walking, bicycling) in 10 months	52	3

Table 2 *Polytomous logistic regression model predicting physical activity level from age, gender and fear of outdoor falling.*

Dependent variable: Physical activity level	Independent variables	OR	95% CI	P value
Low to moderately active	Gender (female) Age (higher) Fear (high)	1.7 1.1 2.9	1.3, 2.3 1.1, 1.2 2.1, 4.2	.00 .00 .00
Active	Gender (female) Age (higher) Fear (high)	.8 1.0 1.5	.7, 1.1 1.0, 1.0 1.1, 2.2	.18 .23 .02
Very active	Reference category			

Table 3 *Logistic regression model predicting outdoor falls from level of outdoor physical activity.*

Dependent variable:	Independent variables	OR	95% CI	P value
Persons with at least 1 outdoor fall	Gender (Female)	2.0	1.1, 3.7	.02
	Age (in years)	1.0	.9, 1.0	.63
	Level of outdoor physical activity - Low to moderately active - Active - Very active	 1.0 2.8 2.6	 1.2, 6.3 1.1, 6.1	 .01 .03

Table 4 *Logistic regression model predicting persons with at least 1 outdoor fall during walking and bicycling from fear of outdoor falls with and without outdoor physical activity and with gender and age as fixed variables.*

Independent variables	Logistic regression model; physical activity included			Logistic regression model; physical activity excluded		
	OR	95% CI	P value	OR	95% CI	P value
Gender (Female)	1.7	.9, 3.2	.09	1.6	.9, 2.9	.17
Age (in years)	1.0	.9, 1.0	.57	1.0	.9, 1.0	.14
Fear of outdoor falls						
- Low	1.0			1.0		
- High	2.0	1.1, 3.9	.03	1.7	.9, 3.2	.10
Outdoor physical activity						
- Low to moderately active	1.0					
- Active	3.1	1.4, 7.1	.00			
- Very active	3.0	1.3, 7.1	.01			

Discussion

At least 22% of our sample of individuals older than 65 years living in the community reported regularly being afraid of falling outdoors (high fear). On the basis of the TDHT, we assumed that outdoor physical activity would mediate the relation between fear of falling and involvement in outdoor falls. This proved to be the case. We found that a high fear of falling outdoors was associated with a low to moderate level of outdoor physical activity (walking, bicycling), indicating that people who perceived themselves at risk of outdoor falls adjusted their behavior by reducing exposure. A low to moderate level of outdoor physical activity was associated with few falls during walking and bicycling, showing that by decreasing their outdoor activities people can diminish the chance that they fall outdoors. However, if these people did venture outside, they were likely to fall down (see table 4). Our results support the assumptions of the TDHT, which has important consequences for research and practice.

According to the TDHT, an increase in fear of falling (an increase in perceived task difficulty to control body posture) will change behavior, which may mask the impact of risk factors or preventive intervention strategies if the outcome measure of a study is involvement in falls or number of falls.[14] Our results show that people who are afraid of outdoor falling are not identified as actually being at risk, if their reduced outdoor physical activity is not taken into account (see table 4). In addition, if fear of falling is reduced by an intervention, people may increase their level of activity, as was observed by Fiatarone et al.[15] and McMurdo et al.[16] This will lead to underestimation of the impact of the intervention if the level of physical activity is not monitored and taken into account when the results are evaluated. For example, Rubenstein et al.[17] found a reduction in falls after exercise training among men only after correction for differences in physical activity. We conclude that the observation that older people compensate for their fear of (outdoor) falls by changing their level of physical activity implies that outcome measures in falls research should include a measure of (outdoor) physical activity.

Regarding the practical consequences of our results, if people are told about their risk of outdoor falls, they will tend to reduce their level of outdoor physical activity because of their increased fear of falling, as shown previously.[18] However, this decrease in the number of falls is achieved at the cost of decreased physical activity in the population. In the long term, lower levels of physical activity increases muscle weakness. This will in turn increase the risk of falling if persons are not able or willing to reduce physical activity furthermore, for instance if the ability to live independently requires a certain minimum level of physical activity.

Conversely, the potential health benefits of increased physical activity among older people[19] do not apply to those involved in falls. The WHO Europe[20] recommends the promotion of physical activity as a means to reduce falls among older people. The findings of this study underline their concerns that increased physical activity can increase the rate of falling due to higher fall risk exposure. This stresses the importance of increasing the physical capability of older people at risk for falls in a relatively safe environment, before they are encouraged to take up more outdoor activities. We consider it important to identify and promote relatively safe physical (outdoor) activities in order to increase at the same time the physical activity and capability, without increasing the incidence of falls. More research is needed to identify (outdoor) activities that can be considered as relatively safe.

A limitation of the study was the low (24%) proportion of participants who took part. The high non-response might be because the main study 'Safety in your own hands' requires a participation commitment of about three years,[12] which may have discouraged the relatively older, less physically active, potential participants. This is borne out by the higher non-response among the relatively older individuals. Regardless of this lower response, our study population was appropriate for the aim of the study, namely, to study the relationships between different variables, which requires that respondents are distributed among all categories of the relevant variables. The Medical Ethics Committee did not allow to ask participants who dropped out during the follow-up for their motives. Therefore no information is available about their specific reasons.

The percentage of outdoor fallers over 10 months (3%) is lower than the percentage

(about 12% per year) found in other studies,[1,21,22] as well as the percentage of indoor fallers. The high drop out of relatively older persons as well as the relatively good condition of walking and cycling paths in the Netherlands, might have contributed to the low percentage of fallers in the study.
A restriction of the study is that it is limited to outdoor falls during walking and bicycling, and therefore our results cannot be generalized to falls indoors. Moreover, the (behavioral) factors involved in falls indoors are most probably different from those falls outdoors.[22] For instance, it is not feasible to reduce indoor physical activity to the extent that is possible to reduce outdoor activity without compromising the ability to live independently. Consequently, the homeostasis theory applied to indoor physical activity and indoor falls might appear to operate differently from outdoor situations. More research is recommended on behavioral aspects of indoor falls.
The relationship between fear of outdoor falls and restriction of outdoor physical activity was based on cross-sectional data and does not imply a causal relationship. However, in some studies people reported that they restricted their physical activity because of a fear of falling.[3,9] For this reason, we feel that a causal relationship between restriction of outdoor physical activity and fear of falling outdoors could be assumed.

Conclusions

We conclude that the level of outdoor physical activity mediates the relation between fear of falling outdoors and outdoor falls, as predicted by the Task Difficulty Homeostasis Theory. It seems that older persons with high fear of outdoor falls restrict their outdoor physical activity in order to prevent an increase in outdoor falls. This implies that the incidence of falls or fallers as outcome measure in research does not adequately represent the impact of risk factors or preventive interventions. It suggests that the level of physical activity should also be taken into account. To reduce falls outdoors, older people should first build up their physical abilities in a safe environment before being encouraged to increase outdoor physical activity.

Acknowledgements

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Chapter 5[b]

Fragility, fear of falling, physical activity and falls among older persons: Some theoretical considerations to interpret mediation

Wijlhuizen GJ, Chorus AM, Hopman-Rock M.

Prev Med 2008; 46:612-614

Abstract

Background

In their letters to the editor, Lacharez et al. and Hafeman & Schwartz questioned the correctness of using the term ‘mediation’ in our paper. In this paper, we concluded that (outdoor) physical activity mediates the relationship between fear of falling and outdoor falls. We investigated whether the term ‘inconsistent mediation’ might be a more appropriate term to use in this context.

Methods

Based on literature, we describe the relationship between fear of falling, physical activity, and falls within a causal model.

Results

Two causal pathways between fear and falls exist, with the causal pathway going from fear of falling via physical activity to falls counteracting (is inconsistent with) the causal pathway going from Fear of falling via hesitancy to falls.

Conclusion

The term ‘inconsistent mediation’ might be more appropriate to describe the causal relationships between fear of falling, falls, and physical activity.

Introduction

In their letters to the editor, Lacharez et al.[1] and Hafeman & Schwartz[2] questioned the correctness of using the term 'mediation' in our paper[3]. In this paper, we concluded that (outdoor) physical activity mediates the relationship between fear of falling and outdoor falls. Both letters suggested that it would be more appropriate to use the term 'suppression', and expressed the need for a theoretical basis for the terminology used to describe this relationship. Lacharez et al.[1] specifically mentioned the lack of evidence for assuming a causal relationship between fear of falling and falls.
The purpose of this letter is to describe the relationship between fear of falling, physical activity, and falls within a causal model, and investigate whether the term 'inconsistent mediation' might be a more appropriate term to use in this context.

Theoretical considerations: a hypothesized causal model of falls

People fall when it becomes too difficult for them to control their balance, that is, when the demands on balance control (e.g.: exposure to indoor and outdoor environmental influences) at a certain point in time become greater than their capabilities (body function) to control balance.[3] For the current purpose only the following three factors which theoretically independently increase the risk of falling (figure 1) are included in the causal model. Other factors related to falls are not addressed because they are not regarded as relevant for the purpose of this letter.
The first factor is fragility (also referred to as frailty[4]). All other factors being equal, increased fragility increases the risk of falls because the decline in body functions that underlies fragility leads to a diminished capability to control balance. Evidence for this relationship comes from Pluijm et al.[5] and Delbaere et al.[6]
The second factor is hesitancy due to fear of falling. People who are afraid of falling frequently shift their control of balance from a fast to a slow mode of control.[7,8] In the fast mode, balance control takes place automatically, without noticeable conscious involvement. In this mode, information from the periphery activates the most adequate coordinative structures.[7] In the slow mode, balance control is largely cognitive and the execution of movements takes place with substantial conscious involvement and is often dependent on visual information.[7,8] In this slow (hesitancy) mode of control, less adequate coordinative structures are involved, which implies that balance control might be reduced.[7] Evidence for this mechanism is found in studies showing an increased fear of falling to be independently associated with reduced balance control[9,10] and fear of falling to be a predictor of falls independent of factors related to physical frailty.[5,6] Therefore, we conclude that there is evidence to

support that fear of falling, leading to hesitancy, reduces balance control capability and is causally related to an increased risk of falling.

The third is factor is physical activity, which increases balance control demands by increasing exposure to various environmental influences. In our study,[3] we found that increased outdoor physical activity was associated with increased risk of outdoor falls.

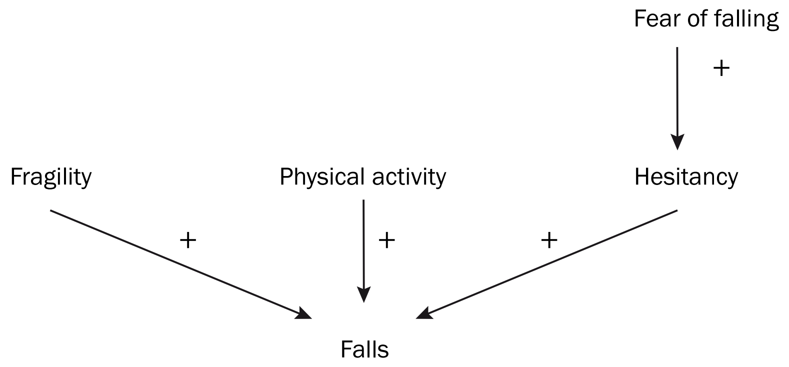

Figure 1 *Independent causal relationship of falls with hesitancy, fragility, hesitancy (due to fear) and physical activity.*

Our causal model which is presented in figure 2 links fragility, fear of falling, physical activity, hesitancy, and falls, and is based on the two schematic models suggested earlier by Hafeman & Schwartz.[2] The signs between variables in figure 2 do not represent statistical associations, but theoretical causal relationships. The proposed causal mechanism starts with increasing fragility as individuals become older. Apart from increasing the risk of falls, fragility also leads to a fear of falling as individuals become aware of their difficulty controlling their balance. Evidence for this relationship comes from a study by Friedman et al.,[11] who showed that women with a history of stroke were at risk of falls and also at risk of developing fear of falling at follow-up. In addition, fragility is often found to be associated with fear of falling.[12,13] In turn, fear of falling causes hesitancy, which also increases the risk of falling. However, once older individuals perceive that they have more difficulty controlling their balance and become afraid of falling, they tend to reduce or avoid this difficulty by, for instance, withdrawing from demanding situations (e.g., uneven pavements, walking stairs) in order to remain in control of balance. Therefore it is suggested that fear of falling causes a reduction in physical activity (negative sign in figure 2). Subsequently, the reduction of physical activity causes a reduction of falls (negative sign in figure 2), because reduction of physical activity is a protective strategy against falling, at least in the short term.[3]

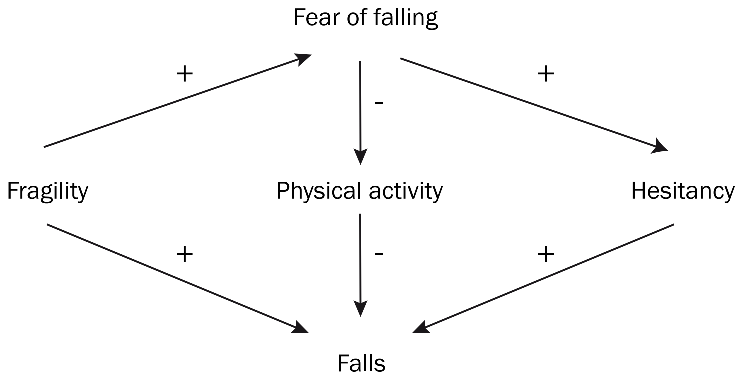

Figure 2 *Hypothesized causal model linking fragility, fear of falling, physical activity, hesitancy, and falls.*

Conclusion

In this model (figure 2), the reduction in physical activity (the indirect pathway) due to fear suppresses the counteracting effect of a combination of fragility and hesitancy. Two causal pathways between fear and falls are assumed, with the causal pathway going from Fear of falling via Physical activity to Falls counteracting (is inconsistent with) the causal pathway going from Fear of falling via Hesitancy to Falls. These causal paths operate within a relative small time frame, because in the long term, the protective effect of reduction of physical activity will diminish due to declining abilities.

On the basis of this model, and as suggested by Lacharez et al.,[1] the term 'inconsistent mediation'[14,15] might be more appropriate to describe the causal relationships between fear of falling, falls, and physical activity.

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Chapter 6

Individual behaviour in the control of balance: the Balance control Difficulty Homeostasis model for falls among older persons

Wijlhuizen GJ, Schuller AA, Todd C, Zijlstra W, Zijlstra R, Hopman-Rock M.

Submitted

Abstract

Introduction
While it is important to prevent falls among older people from a public health point of view, older people themselves do not necessarily consider this important.

Method
This article describes the conceptual framework of a model for controlling balance and preventing falls: 'the Balance control Difficulty Homeostasis model for falls among older persons' (BDH model). The BDH model describes a homeostatic mechanism by which people strive to maintain a preferred safety margin between the capability to control balance and the demands made on this control of balance by physical activity.

Results
According to this model, a person modulates his/her behaviour, e.g.: changes walking speed, shifts attention, or avoids physical activity, on the basis of the perceived or anticipated difficulty in controlling balance and not primarily on the basis of the estimated likelihood of falling.

Conclusion
The BDH model suggests that a diminished capability to judge the difficulty of controlling balance and the acceptance of a smaller safety margin are factors that increase the probability of falling but do not prompt the individual to take specific measures to prevent falls. Implications for research and interventions are discussed.

Introduction

Many older people fall, and it is reported that about 33% people aged 65+ and up to 50% of women aged 85 years and older fall at least once a year.[1,2]
Falls, often defined as 'An unexpected event in which the participants come to rest on the ground, floor or lower level',[3] may result in admission to a nursing home,[4] increased fear of falling,[5] serious injuries such as hip fracture,[6] related high mortality and morbidity,[6] higher costs of healthcare,[7] and a reduced quality of life. From a public health point of view, falls prevention is an important issue,[8] although older people themselves do not always consider this to be a priority issue. This lack of priority given to the prevention of falls is not fully understood[9] and may result in poor participation in falls prevention programmes.
This article describes the conceptual framework of a new model, the Balance control Difficulty Homeostasis model for falls among older persons (BDH model), that takes into account the older person's perception of how well balance can be controlled. The concepts are based on the 'task-capability interface (TCI) model' of Fuller.[10]

The BDH model

General concepts
When a person falls, one or more risk factors have contributed to a situation in which that individual, without intention, loses control over their balance.[11] Two general factors affect the control of balance. The first is the actual physical and mental capability to control balance, and the second represents circumstances or demands that affect this capability to control balance (e.g.: uneven pavements, darkness, high walking speed). In order to successfully control balance during physical activity, a person's actual capability to control their balance has always to be higher than the situational demands made on this capability. The central issue is, how does a person manage to do this?
Analogous to Fuller's TCI model[10] we propose that in order to control balance, people need to make appropriate decisions about their physical activity performance, based on the ongoing perception of their capability to control their balance and the actual and expected demands of the situation in which they have to keep their balance. This 'decision-making process' for controlling balance occurs both automatically and consciously. For instance, a person with a limited capability to control their balance, who perceives an increased demand to control their balance (crowd of people closely passing by) will automatically tend to walk more slowly or will decide to avoid crowded areas in order to remain in control of their balance. Examples of the

interaction between a person's perception of their capability and the demands made on this capability are given in table 1.

Table 1 *Examples of scenarios describing a person's loss of control of balance*

An older person feels tired and has increasingly severe low-back pain after walking for an hour. Walking home usually takes another 20 minutes.	
Person loses control of balance	**Person does not lose control of balance**
Usually the person rests; however, today visitors are expected. The person doesn't take a rest and hurries to get home. The low back pain suddenly gets worse and the person does not lift their feet properly. The person hits a small obstacle on the pavement and loses control.	As usual, the person takes a rest, and if the pain doesn't feel better, he/she usually takes a taxi or bus to get home.
As usual, no rest is taken. The person is used to feeling tired and having low-back pain. The temperature drops unexpectedly and the person's legs and feet become cold. The person does not notice that he/she has become less flexible and he/she cannot compensate for a sudden small skid.	As usual, the person doesn't take a rest. However, she/he pays special attention at well-known difficult spots (road crossing, steep stairs uphill) and adjusts her/his walking speed.

The BDH model (figure 1) describes the concepts and processes that are involved in the control of balance. Each concept is described below, starting from the top of the model. First, the distinction is made between the actual and the perceived difficulty of controlling balance. 'Actual' refers to the real difficulty of controlling balance when performing a physical activity and is based on the person's physical and mental abilities and environmental conditions, and 'perceived' refers to a person's anticipated difficulty of controlling balance while performing or planning a physical activity and is based on that person's perception of their physical and mental abilities and their experience of similar situations.

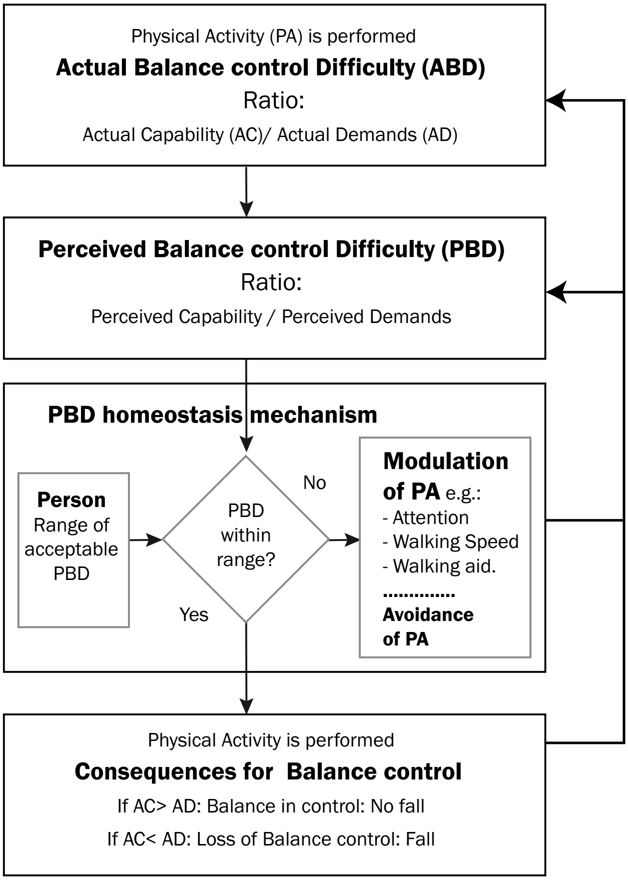

Figure 1 *The Balance control Difficulty Homeostasis (BDH) model for falls among older persons.*

The model describes the Actual Balance control Difficulty (ABD) as a person is performing a physical activity (PA) that is equivalent with the ratio of Actual Capability (AC) and Demand (AD) to control balance. At the same time, the person perceives the Balance control Difficulty (PBD). In the PBD homeostatic mechanism, the person evaluates whether the PBD is within the range of acceptable PBD. If not, PA is modulated or avoided; otherwise PA is performed as planned. If during that activity AC exceeds the AD, no fall occurs; however, if AD exceeds the AC, loss of control of balance occurs resulting in a fall. All outcomes of the homeostatic mechanism may influence ABD as well as PBD.

Actual Balance control Difficulty

When performing a physical activity, the difficulty a person has in controlling their balance is equivalent to the ratio between that person's capability to control their balance and the situational demands made on this capability. The closer the person's capability to control their balance approaches the demands made on this capability, in other words, if the so called 'safety margin' becomes smaller, the more difficult it will be to control balance.[12]

However, it should be noted that the difficulty of controlling balance while performing an activity is not constant but instead fluctuates. It is affected by situational demands, such as the surface, light and weather conditions, the availability of handrails, etc, but also by the person's actual psychological and physiological capability to control their balance, which also changes because the person may become fatigued or distracted while performing the activity.

Perceived Balance control Difficulty (PBD)

While a person does not know the actual difficulty of controlling balance, through observation and evaluation/assessment they will form an impression of, or perceive, the real difficulty. The level of perceived difficulty is inversely related to the difference between a person's ongoing perception of their capability to control balance and the perceived demands. For instance, a person who experiences increasingly severe low back pain and tiredness while walking outside at dusk in a poorly lit environment perceives that it is increasingly difficult to control their balance. If a person notices that it is increasingly difficult to control their balance, the process of controlling balance will become more conscious and less automatic.[13] Moreover, the person will perform fewer activities simultaneously; for example, they will stop to talk instead of talking while walking.[14]

The perceived difficulty of controlling balance may deviate from the actual difficulty, because the person may not have sufficient information to determine the actual difficulty of controlling balance; for instance, if they do not notice that part of the floor is slippery.

Perceived Balance control Difficulty homeostasis mechanism

A central mechanism of the proposed BDH model is that a person behaves in such a way as to keep the level of perceived difficulty of controlling balance within acceptable limits (target limits).[10] According to the heuristic of perceived task difficulty,[10] the perceived task (balance control) difficulty is compared to what is considered acceptable. If the perceived difficulty of controlling control balance is considered acceptable, the physical activity is performed as planned. If it is considered unacceptable, a strategy may be applied to modulate the perceived difficulty, that is,

the physical activity will be performed differently (e.g.: more/less cautiously, using a walking aid). However, if the perceived difficulty remains too high, the physical activity will be avoided.
The behavioural adjustments (modulations) are homeostatic in nature: they keep the perceived difficulty of controlling balance within an acceptable (to the person concerned) limit. This also implies that if the anticipated difficulty is below or at the low end of what is considered acceptable, a person may increase the perceived difficulty by, for example, climbing stairs without using the handrails, leaving walking aids at home while walking outside, or allowing themselves to carry a shopping bag.

Consequences for Balance control
If physical activity is avoided, no demands will be made on the capability to control balance; the person will not become out of balance and will not fall. Thus if a person often avoids physical activity, with time they will become less able to control balance because of a lack of experience and training (e.g.: loss of skill).[15] This may lead to an increased actual and perceived difficulty of controlling balance.
If a person performs a physical activity and their capability to control balance exceeds the demands made on this capability, they will not fall. However, if a person overestimates their capability to control their balance and the situational demands exceed their capability to control balance, that person will lose control over their balance and fall. Depending on the resulting injury, that person's capability to control their balance may decrease, resulting in a greater perceived difficulty of controlling balance. Moreover, the person may no longer be able to perceive their capability to control balance accurately because it has decreased to a level that is unusual for the person. Even if a person is not injured by the fall, their perception of the difficulty of controlling their balance (fear of falling) may increase, and the physical activity may be avoided or a modulation strategy may be applied.

Discussion

From a public health point of view, the prevention of falls among older people is important because of the high incidence and serious consequences of falls. Yet older people appear not to be concerned about these issues because the uptake and adherence to falls prevention programmes is poor.[9] The BDH model is based on the TCI model and emphasizes the importance of individual behavioural choices to the control of balance.[10] Analogous to the TCI model,[10] the BDH model assumes that older people control their balance primarily by adjusting their behaviour, based on the perceived difficulty of controlling balance and not on their own estimation of the probability of falling. As long as older people consider the perceived difficulty of controlling balance to be acceptable, they will not try to improve their capability to control balance even though their actual probability of falling is high. This may in part explain why many older people do not participate in falls prevention programmes.

Perceived balance control difficulty, fear of falling and physical activity

The BDH model assumes that if a person perceives the difficulty of controlling balance to be unacceptably high, that person will tend to reduce the demands made on their capability to control balance by, for example, avoiding physical activities.

Fuller[10] showed that the perception of task difficulty was strongly correlated with feelings of risk, which represent an emotional response to a threat, such as fear.[16] The perception of task difficulty and fear appeared to be critical determinants of the behaviour of drivers (reducing speed). In an analogous manner, the BDH model predicts that the decision to be physically active is determined by the perceived difficulty of controlling balance and the emotional reaction to a threat, in this case fear of falling. Several studies have shown that a high level of fear of falling is associated with decreased physical activity in older people[5,15,17-19] presumably modulated by a high perceived difficulty of controlling balance. This latter relationship was studied recently (unpublished data) among 333 community-dwelling older people (75+), who were asked in a questionnaire to rate the difficulty of controlling balance for several physical activities (such as, walking, climbing stairs, taking a shower). Analysis revealed that a greater difficulty of controlling balance was associated with a lower frequency of actually performing these activities. In addition, some studies have reported a diminished fear of falling and increased physical activity in older people participating in physical exercise programmes,[20,21] possibly as an increased capability to control balance. These results support the assumed relationship between an emotional reaction to a threat (e.g.: fear of falling), perceived difficulty of controlling control balance, and behavioural modulation. They also support the concept of the homeostatic nature of human behaviour in relation to fear of falling, but this needs further verification in empirical studies of each concept, not only for the level of physical activity, but also for other modulation strategies such as using walking aids, handrails or avoidance of certain areas with uneven pavements or crowds of people.

Adequacy of perception of the actual balance control difficulty

In the BDH model, an accurate perception of the actual difficulty of controlling balance determines whether a person loses control of body posture. The accuracy of this perception is decreased if the actual capability to control balance and the demands made on this capability fluctuate, or if a person's mental functioning is reduced.

Physically frail older people with a high fall risk not only appear to have a diminished capability to control their balance but also have a relatively high number of transitions as they become less mobile.[22,23] In addition, the haemodynamic[24] and neuromusculoskeletal,[25,26] changes that occur when a person changes position may reduce a person's capability to control their balance. If the person does not perceive or underestimates these changes, they may underestimate the difficulty of controlling their balance and subsequently fall.
However, older people may realize that their actual capability to control their balance is becoming unpredictable. In this situation, accurate perception and estimation of the demands made on balance control will become more important. Perception of these demands will improve if unexpected fluctuations in the demands are reduced, which could explain why frail older people limit their activities to familiar environments and as a result become less physically active.
Various studies have shown that dementia[4,27] and the use of psychotropic medication[28,29] are risk factors for falls. These results also support the assumption that a diminished perception of the difficulty of controlling balance is associated with falls.

Acceptance of the perceived balance control difficulty

The BDH model assumes that individuals "set" limits to what they consider an acceptable perceived difficulty of controlling balance. In general, individuals prefer to have a relatively broad margin of safety between the demands made on their capability to control balance and their real capability. However, many older people perceive the difficulty of controlling balance during the performance of physical activities to be high.[30] Some show signs of a deterioration of balance control, such as reduced step length and walking speed, increased visual control during walking, signs which may be regarded as indicators of a small safety margin between the capability to control balance and the demand. Why then, do these older people still perform physical activities even if they perceive the safety margin to be very small?
Three psychological mechanisms undermine the maintenance of safety margins.[31] First, motivational conditions, such as living independently, undermine the maintenance of safety margins because certain essential physical activities with a fixed level of demand have to be performed, even if the capability to control balance is diminished. Second, a growing desensitization to potential threats may occur if the threats are not realized. Although the perceived difficulty of controlling balance will gradually increase, the person may negate this increased difficulty if they do not lose their balance and fall. Finally, even if a person loses their balance and falls, this is considered to be a rare event by most older people, perhaps occurring once a year at most. Indeed, an individual may have performed 'dangerous' activities in the past

without deleterious consequences, and it seems that older people often base their perceptions within the context of their whole life, rather that the current period of reduced capability.[32] For these reasons, older people may not feel it worth their time, money, and energy to participate in falls prevention programmes.

Implications

Although support for the BDH model can be found the literature on falls, the homeostatic mechanism and related acceptable target levels of task difficulty require further study. Thus the model should be considered as a conceptual framework that needs further research-based testing and refinement. Nevertheless, the model has implications for research and practice in risk assessment and falls prevention among older people.

The model describes several mechanisms that contribute to explaining why older people will not feel the need to take specific preventive measures against falls. Older people experience that they can control their balance quite adequately by changing the level of physical activity. Moreover, older people tend to accept a smaller safety margin between the capability to control balance and the demands made on them to control their balance, and become less accurate in estimating the difficulty of maintaining their balance. Thus in order to assess the actual impact of risk factors for falls, estimation of the fall risk should include the level of physical activity as a measure of exposure, because older people reduce their level of activity; thereby increasing their balance control and in fact prevent falls.[19,33] As reducing physical activity may subsequently lead to a further reduction in the capability to control balance,[15] falls will start to happen if people are not able to reduce their physical activity to a level that is consistent with their capabilities. The focus of an intervention strategy for falls prevention should therefore be primarily to maintain or increase the capability to control balance before falls actually start to happen. Moreover, if the capability to control balance is diminished by illness or immobility, steps should be taken to increase this capability in a safe environment, where the person can accurately estimate the demands made on them. Lastly, if falls prevention programmes focus on older people, they may reduce their level of physical activity because of a fear of falling, or they might misunderstand the message because they do not consider themselves to be at risk of falling, feeling confident in their capability to control their balance. Therefore, the issue of falls prevention should be primarily addressed to professionals who are involved in healthcare and welfare of older persons. These professionals should screen, and if necessary treat, those factors related to emerging gait and balance problems before older people start to reduce their physical activity and in the end lose control of their balance.[34]

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Chapter 7

The FARE: a new way to express FAlls Risk among older persons including physical activity as a measure of Exposure

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Submitted

Abstract

Objectives

Many commonly used ways to express falls risk do not include exposure to hazards. We compared two expressions of falls risk among community dwelling older persons: the commonly used population incidence (fallers per 1000 person-years) and the new FAlls Risk by Exposure (FARE), expressed as the number of fallers per 1000 physically active person-days.

Methods

Prospective follow-up study among community dwelling older persons (N=771). Baseline data on age, gender, disabilities (vision, mobility), and number of days per week with minimally 30 minutes of physical activity were collected. Falls were registered monthly. Falls risk was expressed as the number of falls per 1000 person-years and as the number of falls per 1000 physically active person-days (FARE). A balance control difficulty score was based on the sumscore of 11 disability items.

Results

Increased difficulty controlling balance was linearly associated with reduced exposure to risky situations (Spearman correlation coefficient= -.56) and to an increased falls risk per 1000 person-years. In contrast, the FARE score increased exponentially.

Conclusions

The FARE is recommended for use in public health policy and research on falls prevention because it takes into account the risk compensation behavior of older persons who experience increased difficulty controlling their balance.

Introduction

From a general perspective, accident or injury risk is the probability of having an accident or injury per unit of exposure.[1] A unit of exposure can be regarded as a trial, which can result in the occurrence or non-occurrence of an accident or injury.[2] The risk of accident or injury can be expressed in several ways. For example, the population incidence (number of cases per 1000 person-years), but also the number of cases per 1000 person-hours of involvement in related activities,[3-6] or with regard to traffic, the number of cases per 1000 person-miles driven.[7,8] The denominator in each of these latter expressions is a measure of exposure to the hazard that is involved in participation in the activity.

The significance of using exposure data in risk analysis was addressed by Hale and Glendon.[9] "If a person carries out a particular activity many times and occasionally it goes wrong enough to result in an accident, very different interventions will be necessary to improve matters, compared with instances where a person carries out an activity infrequently, but it almost always goes wrong. Data on the exposure to the hazard or on demands for specific actions must therefore form as fundamental a part of the analytical database of health and safety as records of accidents and occupational diseases." However, exposure data are often not measured in studies of falls among older persons. The risk of falls is commonly expressed as the number of falls or fallers per 1000 person-years, as recommended by Gillespie[10] and Lamb et al.[11] Nevertheless, Todd and Skelton[12] addressed the role of exposure when discussing risk factors: "Some studies suggest a U-shaped association, that is, the most inactive and the most active people are at the highest risk of falls.[13,14] This reveals the complex relationship between falls, activity, and risk. The type and extent of environmental challenges that an older person chooses to embrace interact with the person's intrinsic risk factors." According to Skelton[15] and Jorstad-Stein et al.,[16] while exercise has a beneficial effect on a person's balance, it can also be considered a general measure of that person's exposure to hazardous situations that put demands on that person's ability to control balance. Indeed, some studies found indications that increased physical activity was associated with an increased falls incidence per 1000 persons-years. Wijlhuizen et al.[17] found that outdoor falls occurred more often among persons who walked and bicycled more frequently, and Ebrahim et al.[18] reported that brisk walking may increase the risk of falls. Therefore, a measure of the level of physical activity could be an appropriate measure of exposure to falls. This is supported by the observation that older persons tend to reduce their level of physical activity as they become afraid of falling.[17,19] Thus reducing exposure to hazards could be seen as a behavioral response to perceived difficulties controlling balance in order to maintain balance control.[20] This tendency to reduce exposure to hazards may be reinforced by the person feeling less unsure of their balance when fewer demands are made on their ability to maintain balance. In fact, the person seems to be preventing falls [17] and also perceives this as a way of preventing falls.[21,22]

From the perspective of public health, this tendency to reduce exposure to challenging situations has two important consequences. First of all, when identifying persons at risk of falls (per 1000 person-years), persons will not be classified as being at risk as long as they are able to reduce exposure sufficiently to compensate for their difficulty in controlling balance. Secondly, in the long-term, reducing exposure to hazards contributes to inactivity, which contributes to increased and probably more complex problems in controlling balance,[23] ultimately increasing the risk of falls. The complexity of the balance control problems will require relatively complex multifactorial interventions to prevent future falls,[24] interventions that have not been proven to reduce falls related fractures or other injuries[24,25] that are perceived as a major public health problem.[12]

Therefore, a new way to express the risk of falls among older individuals is needed that incorporates physical activity as a measure of exposure. This expression takes into account the tendency of older persons to reduce exposure to hazards as their difficulty controlling balance increases. Thus the risk of falling will increase if a person reduces their physical activity even if their falls incidence per 1000 person-years does not increase.

The objective of this study is to compare and discuss two expressions of falls risk among community dwelling older persons: the commonly used population incidence (fallers per 1000 person-years) and the new FAlls Risk by Exposure (FARE), expressed as the number of fallers per 1000 physically active person-days.

Methods

Subjects

A questionnaire was sent to 2500 community dwelling older persons aged 71 and older in Heerenveen and Drachten (middle-sized Dutch towns). The subjects were randomly drawn from the local registry office from four stratified age (five years) categories. Older subjects were overrepresented in the sample because a higher non-response was expected among these individuals. All subjects, mean age of 80.1 years and 40% men, were asked to participate in a prospective follow-up study; 771 (31%) agreed to participate (figure 1).

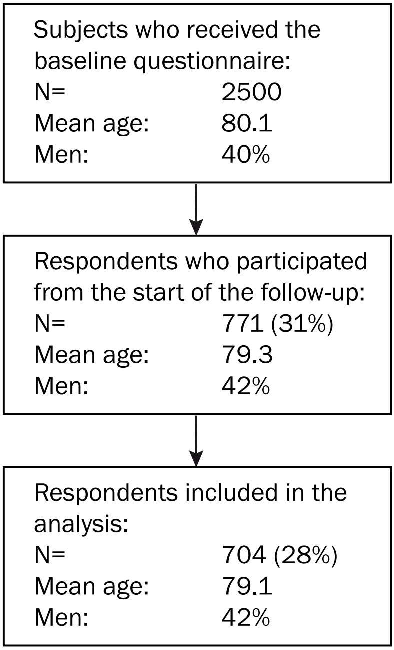

Figure 1 *Flow chart showing the stages in the study procedure and numbers of subjects and respondents by age and gender*

Falls, balance control difficulty, and physical activity

The baseline questionnaire contained questions about age, gender and specific disabilities (difficulty with nearby vision, distant vision, carrying a 5 kilo bag for 10 meters, walking 400 meters without stopping, independent use of the toilet, bending to pick up an object, getting out of bed, walking across rooms at the same level, getting up from a chair, walking stairs, walking after getting out of bed). The level of difficulty performing each activity was scored as (1) no, (2) moderate, (3) severe difficulty, (4) not able to perform. In addition, at baseline questions were asked about the number of days a week in which subjects were physically active at a moderate level (such as brisk walking or bicycling) for at least 30 minutes, separately for summer and winter,[26] as a measure of exposure. At follow-up, for 10 months all subjects were automatically telephoned monthly by a computer system using voice recognition technology, and asked for involvement in falls. If a fall was reported, within a week a personal telephonic interview was held about the circumstances of the fall (e.g.: time and location). The procedure is described in more detail in Wijlhuizen et al.[27]

Statistical Analysis
Subjects with a missing value for one of the disability items or the exposure measure were excluded from analysis. The number of persons who fell at least once inside or outside the home during day-time (from 8 a.m. to 12 p.m.) was taken as an indicator of the risk of falling; falls occurring at night were excluded.
The indicator of the difficulty controlling balance was calculated by summing the difficulty scores (1 to 4) for the 11 disability items, based on findings from Era et al.[28] The total score for balance control difficulty varied from 11 (no difficulty on all items) to 38 (not able to perform almost all of the activities). Four categories were constructed, taking into account the skewness of the distribution of difficulty scores:(1) No difficulty (scores: 11-14; n=365, 52%); (2) Slight difficulty (scores: 15-19; n=177, 25%); (3) Moderate difficulty (scores: 20-25; n=110, 16%); (4) Severe difficulty (scores: 26-38; n=52, 7%).
The exposure measure was constructed by summing the number of days a week, in summer and winter, that a person was physically active for minimally 30 minutes; the score ranged from 0 to 14. We then assigned a score 1 to those subjects reporting 0 physically active days, because zero physical activity (including low intensity level) was assumed not realistic for most community dwelling individuals. Therefore, an exposure score of 1 indicates that a subject is physically active for 30 minutes less than 1 day a week, in summer or winter. Subsequently, the number of physically active days in an average week over a year was computed by dividing the range of 1 to 14 physically active days by two; resulting in a range of exposure of 0.5 to 7 days.
The association between the level of balance control difficulty and exposure was computed, using the Spearman rank correlation. As outcome measures, we calculated falls risk in two ways, namely, based on the ratio between the number of fallers in each category per 1000 person-years, and per 1000 physically active person-days (the FARE) in this category. For both expressions, the falls risk ratios were computed using the ‘no balance control difficulty’ group as a reference group.

Results

In total 771 community dwelling persons (42% men) aged between 71 and 96 years (mean age men: 79.4 (sd 4.3), women: 79.2 (sd 4.3)) participated in the follow-up period of 10 months. In total, 205 persons fell 376 times in 771*10/12 person-years; an incidence of 319 fallers per 1000 person-years. Between 8 a.m. and 12 p.m., 176 persons fell at least once; an incidence of 274 per 1000 person-years. Among the 704 respondents who were included in the analysis (figure 1), 42% were men (n=294); mean age for men was 79.3 (sd=4.1) and for women 79.0 (sd=4.3), as shown in table 1.

Table 1 *Subjects included in the analysis by age and gender*

	Men		Women		Total	
Age	**N**	**(%)**	**N**	**(%)**	**N**	**(%)**
71-75	50	17%	96	23%	146	21%
76-80	148	50%	189	47%	337	48%
81-85	73	25%	96	23%	169	24%
86+	23	8%	29	7%	52	7%
Total	294	100%	410	100%	704	100%
% of Total		42%		58%		100%
Mean age	79.3		79.0		79.1	

The level of difficulty of performing the various disability items is presented in table 2. 'Independent use of the toilet' and 'Walking across rooms at the same level' were least frequently reported as difficult (over 90% reported no difficulty), whereas 'Carrying a 5 kilo bag for 10 meters', 'Walking 400 meters without stopping', and 'Walking stairs' were most frequently reported as difficult to perform (between 21% and 31% reported at least severe difficulty).

We then computed the indicator of balance control difficulty. Among the 704 respondents, in total 154 daytime fallers and 2762 physically active person-days were recorded (see table 2).

Table 2 *Results of baseline questionnaire (disability, physical active person-days) and follow-up falls registration (number of fallers during daytime, per 1000 person-years and per 1000 physically active person-days; the FARE)*

	Level of difficulty (N=704) *			
Disability item	**No (1)**	**Moderate (2)**	**Severe (3)**	**Not able (4)**
Nearby vision (reading small words)	460 (65%)	164 (23%)	39 (6%)	41 (6%)
Distant vision (recognizing face)	590 (83%)	82 (12%)	12 (2%)	20 (3%)
Carrying a 5 kilo bag for 10 meters	357 (51%)	127 (18%)	38 (5%)	182 (26%)
Walking 400 meters without stopping	381 (54%)	153 (22%)	34 (5%)	136 (19%)
Independent use of the toilet	656 (94%)	44 (6%)	2 (0%)	2 (0%)
Bending to pick up an object	420 (60%)	191 (27%)	52 (7%)	41 (6%)
Getting out of bed	605 (87%)	86 (12%)	10 (1%)	3 (0%)
Walking across rooms at the same level	640 (91%)	52 (7%)	7 (1%)	5 (1%)
Getting up from a chair	577 (82%)	106 (15%)	18 (3%)	3 (0%)
Walking stairs	404 (58%)	151 (21%)	56 (8%)	93 (13%)
Walking after getting out of bed	451 (64%)	217 (31%)	36 (5%)	0 (0%)

	Level of balance control difficulty**				
	No (11-14)	**Slight (15-19)**	**Moderate (20-15)**	**Severe (26-38)**	**Total**
Subjects N (%)	365 (52%)	177 (25%)	110 (16%)	52 (7%)	704 (100%)
Fallers at daytime N (%)	60 (39%)	37 (24%)	34 (23%)	23 (14%)	154 (100%)
Physically active person-days N (%)	1865 (68%)	643 (23%)	206 (7%)	48 (2%)	2762 (100%)
Mean per person per week	5.1	3.6	1.9	0.9	3.9
Fallers					
Per 1000 person-years N	197	251	371	531	263
Risk ratio***	1.0	1.3	1.9	2.7	
Fallers					
Per 1000 physically active person-days					
N (the FARE)	32	58	165	479	56
Risk ratio***	1.0	1.8	5.2	15.0	

* Due to missing data the Total N=704 differs from the total number of subjects that participated (N=771), and the number of fallers (176). Each level of difficulty received a quatification (1) to (4).

** Based on sumscore of the level category quantifications over the 11 disability items (ranging from 11 to 38)

*** Category 'No difficulty' is taken as reference category.

The mean level of physical activity, expressed as the number of days that respondents were physically active for at least 30 minutes in an average week (table 2), was 3.9 days (sd=2.5). Individuals who reported no difficulty controlling their balance were about 5 times more active than those who reported severe difficulty controlling their balance (mean 5.1 physically active days versus 0.9 physically active days, respectively). The level of balance control difficulty was inversely associated with the number of physically active days; Spearman -.56; $p < .000$, indicating that the association was significantly different from zero.

Regardless of the method used to express the falls risk, (number of fallers per 1000 person-years and per 1000 physically active person-days), the risk of falls increased with increasing difficulty controlling balance. However, when expressed as the number of fallers per 1000 physically active person-days (the FARE), the risk of falling increased exponentially compared with the linear increase when the risk of falling was expressed as falls risk per 1000 person-years.

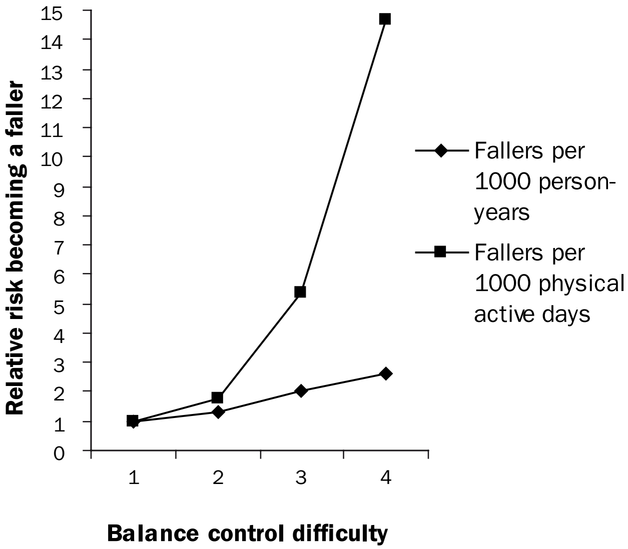

Figure 2 *Relative risk of becoming a faller during daytime with increasing difficulty in controlling balance expressed per 1000 person-years and 1000 physically active person-days (the FARE).*

Discussion

Comparison of two ways of expressing falls risk revealed different patterns of risk as balance control difficulty increased. The falls risk, per 1000 person-years, increased linearly, whereas the FAlls Risk by Exposure (FARE), expressed as the number of fallers per 1000 person-days with at least 30 minutes of physical activity, increased exponentially with difficulty controlling balance. The exponential increase of the FARE was due to the strongly reduced physical activity (exposure) among subjects who reported increased difficulty controlling balance. This reduction in exposure can be interpreted as a behavioral mechanism whereby subjects try to remain in control of their balance as they experience increased difficulty controlling balance. By avoiding involvement in certain physical activities, they reduce demands on their balance control.[19,21,22] By reducing exposure to potentially hazardous (risk of falling) situations, subjects succeed in reducing their falls risk substantially from a relative strong exponential to a moderate linear increase as balance control difficulty increases. This finding questions the suitability of the falls risk measure expressed per 1000 person-years because it is insensitive to exposure reduction among subjects who experience balance control difficulty.

In addition, the level of exposure differed widely among the participants, with subjects without balance control difficulties being about 5 times more active than subjects with great difficulty controlling balance. The insensitivity of the commonly used falls risk measure (expressed per 1000 person-years) to these large variations in falls exposure may have important consequences for the interpretation of data and for public health policy on falls prevention. First of all, this insensitivity results in a large and systematic underestimation of falls risk, compared with that calculated with the FARE expression. It seems to imply that factors that affect balance control among older subjects do not appear to increase their falls risk per 1000 person-years, as persons apparently compensate by reducing exposure to hazards. This might explain the inconsistent findings for the association between measures of balance control and falls per 1000 person-years.[29] In addition, falls risk expressed in this way is not sensitive to changes in exposure that result from interventions that influence risk factors for falls.[10,11] If a falls prevention intervention, for instance balance and mobility training, results in an improved ability to control balance and increased physical activity, but not in a reduction in falls per 1000 person-years, this intervention is generally perceived as being ineffective.[30]

Apart from the issue of sensitivity of the commonly used measure of falls risk, the data presented in figure 2 illustrate that older subjects are quite effective in reducing their falls risk by reducing physical activity. However, this beneficial effect on falls risk is only temporary because reduced physical activity will reduce their balance control capability in the long term.[31] Therefore, subjects who do not fall but strongly reduce their physical activity should also be targeted for falls prevention interventions. They might mask their reduced balance control capability and put themselves at high risk of falling in the future as their balance control capability is reduced to such a level that a further reduction in physical activity is not feasible (e.g.: as getting out of a chair becomes very difficult).

The FARE expression, in which the number of cases (N) is divided by a related measure of exposure (E); FARE = N/E, can be applied to other situations (at home or outside the home), time of day, or activities (e.g.: walking outside the home, bicycling, climbing stairs). While the FARE can be calculated at a population level, as was done in this paper, it can also be applied to indicate the falls risk at the individual level, which is required for performing regression analyses. Then, the outcome measure in falls risk analysis should be the number of falls or being a faller or not, divided by exposure (e.g.: the number of physical active days) of each individual.

Limitations

In order to prevent the falls risk from becoming zero or infinite, two restrictions are required. The first is that respondents who have zero exposure should be excluded from analysis. Conceptually, this restriction is sound if one considers the situation in which the risk of falling from a bicycle is studied and one includes subjects who do not bicycle at all. Those who do not bicycle, and therefore do not fall from a bicycle, might actually have chosen to stop bicycling because of their perceived balance control difficulty. Including these persons in the analyses might strongly reduce the contrasts between fallers and non-fallers. The second restriction relates to the number of falls or fallers (N) in the equation. At the individual level non-fallers should be coded as 1. Those who did fall should be coded as 2 (or higher if their number of falls is higher than one). In this case, FARE = (1+N)/E. Thus subjects with the lowest falls risk were those who did not fall (N=0) and who were physically active 7 days a week (value is 7); their falls risk was 1/7=.14. In contrast, subjects with the highest falls risk are those who fell once or more often (N=1 or higher) and who were inactive (value=.5 in our study); their falls risk was 2>/.5=4 or higher.
At the population level, the number of falls or fallers can be put in the equation if they are greater then 0. If the number of falls or fallers equals zero, one should add one fall or faller identical to the equation at the individual level. In our study, we used the self-reported number of days in which subjects were at least 30 minutes physically active[26] as the measure of physical activity. The current availability of these data in some national physical activity statistics, and the relative ease of obtaining these data are important advantages for using this measure as a general indicator of physical activity. On the other hand, the reliability of self-reported physical activity data needs to be evaluated because there is currently no established measure of physical activity.[16]
The suggested measure of exposure, the number of person-days with at least 30 minutes of physical activity, is not applicable to falls that happen at night (from

12 p.m. to 8 a.m.), because these falls generally happen as subjects are asleep and get out of their beds. The frequency of getting out of bed at night might be a feasible exposure measure, because it is easy to measure (asking subjects) and it involves physical activity.
The balance control variable was used in this study as an example of a potential risk factor for falls to illustrate the differences in risk ratios as presented in figure 2. Replication or comparison of both expressions of falls risk is recommended for other known risk factors for falls, such as medication use or vision disability. The exposure and balance control data were obtained at baseline and falls were reported during follow-up. This limits the reliability of findings because falls, exposure, and balance control data are combined to express the falls risk. To increase reliability, exposure and balance control data should be monitored more frequently during follow-up.

Conclusions

The number of falls per 1000 person-years (as commonly used) does not adequately reflect the falls risk of older individuals because it does not take into account large differences between the level of physical activity of older individuals. Therefore we formulated a new expression of falls risk, the Falls Risk by Exposure (FARE), which includes the level of physical activity as a measure of exposure. The FARE is recommended because it takes into account the risk compensation behavior of older persons who experience increased difficulty controlling balance and reduce their physical activity level. For public health policy for falls prevention, this measure implies that persons at risk for falls can be identified more adequately. Also in the evaluation of falls prevention programs, the impact on falls risk can be determined taking into account the possible changes in exposure due to interventions that improve balance control among persons at risk for falls.

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Chapter 8

General Discussion

Introduction

The main issue addressed in this thesis is the apparent withdrawal of older persons from physical activities that they perceive as too dangerous (too demanding) relative to their capability to control their balance. By doing so, they may reduce their falls risk. Thus individuals may mask their difficulty in controlling their balance by reducing their exposure to hazards (i.e.: by reducing physical activity). The relevance of exposure to hazards as a factor associated with falls risk is generally acknowledged, but until now it has not been addressed systematically in research.[1-4] The aim of the studies described in this thesis was to investigate, within the framework of research into falls risk among older persons, the significance of the level of physical activity as a measure of exposure.

Summary and main findings

Several prospective follow-up studies and secondary data analyses were conducted from 1994 until 2008, to investigate the relevance of physical activity as a measure of exposure. The follow-up studies required a reliable method for establishing whether participants had fallen and the circumstances and consequences of these falls. A major drawback of existing methods was that they were time-consuming to manage and required respondents to take the initiative to report falls. We therefore developed an innovative method to register falls among older persons, using interactive voice response technology: the Telephone Inquiry System (TIS). Respondents were telephoned monthly by a computer and could respond to questions by answering 'yes' or 'no'.

We found that the TIS is feasible in terms of the willingness and ability of older persons to use the system. We also demonstrated that the system is reliable for registering accidents and falls among community-dwelling elderly individuals, as described in chapter 2. The availability of the TIS was an important condition for conducting prospective follow-up studies, not only for the registration of falls but also for obtaining information about the circumstances and consequences of the falls (i.e., location, time, and injury of the fall) from a large number of respondents. The circumstances under which falls occurred appeared to be important for the interpretation of the processes that might be involved in the causation of falls.

In 1999, we used the TIS in the 'Safety in your own hands study', as described in chapter 3. In this study, we evaluated the effect of a multifactor community intervention to reduce all falls (at home and outside the home) among older persons in Sneek in comparison to two control communities (Harlingen and Heerenveen).

Although the number of falls was not reduced, we measured a selective relative reduction in falls outside the home among women. We also found that a low level of participation in outdoor physical activity was associated with this reduction in outdoor falls. Also, a low level of outdoor physical activity appeared to be associated with an increased number of indoor falls, probably because subjects with a low level of outdoor physical activity spent more time at home.
Based on the results of this study, we assumed that the level of indoor and outdoor physical activity is associated with the number of indoor and outdoor falls. Because there were no relevant data in the literature, we performed two studies to investigate this relationship. The first study addressed indoor falls and the second study outdoor falls, each associated with related levels of physical activity.
The first study addressed the association between the 24-hour distribution of the level of physical activity in the home and indoor falls, as described in chapter 4. We found that physical activity was strongly associated with the number of falls in the home, measured over 24 hours. In addition, we found that especially at night the number of falls per 1000 active person-hours was relatively high compared with the number of falls during the day. This indicated that older persons might be at increased risk of falling if they are encouraged, for instance by physical activity promotion interventions, to become more physically active. Also if older persons frequently get out of bed at night, they are frequently exposed to specific night time hazards (i.e.: reduced vision) which increases their risk of falling. Thus in addition to the health-related factors reported in the literature, changes in the level of physical activity should also be taken into account when estimating a person's risk of falling.
The second study addressed the relationship between the level of outdoor physical activity (walking and bicycling) and outdoor falls during walking and bicycling, as described in chapter 5[a]. The aim of this study was to test the assumption that the level of outdoor physical activity mediates the relationship between fear of falling and actual outdoor falls. The results showed that people with a high fear of falling were more often 'low to moderately active' or 'active' compared with people who had no such fears, who were more often 'very active'. While fear of falling was not associated with outdoor falls, it was after the level of outdoor physical activity was taken into account. Older persons with high fear of falling fell more often per unit of physical activity (frequency of outdoor walking or bicycling). We concluded that outdoor physical activity mediated the relationship between fear of falling and actual outdoor falls.
In two letters,[5,6] which questioned the correct use of the term 'mediation' in our article,[7] Lacharez et al. and Hafeman et al. expressed the need for theoretical considerations about the causal relationship between fragility, fear of falling, physical activity, and falls. Because no such causal model was available in the literature, we

developed a hypothetical causal model of falls, as described in chapter 5[b]. On the basis of this model, the term 'inconsistent mediation'[8,9] might be more appropriate to describe the causal relationships between fear of falling, falls, and physical activity. In this model, the level of physical activity is considered as a measure of exposure to hazards which affect balance control.

In chapter 6, we formulated a more elaborate conceptual model of falls from the perspective of individual behaviour in controlling balance: the Balance control Difficulty Homeostasis model of falls (BDH model). A central element of the model is that older persons perceive their own balance control capability and the demands made on it.[4] Older people might experience that they can control their balance quite adequately by changing the level of physical activity. Their falls risk increases as they might tend to accept a smaller safety margin between their capability to control balance and the demands made on them to control their balance.[4] In addition, they might become less accurate in estimating the difficulty of maintaining their balance, for instance because of increased variability of their capability to control their balance.

This newly proposed model is derived from the TCI model of Fuller,[10] which describes the behaviour of drivers. The BDH model describes several mechanisms that contribute to explaining why older people generally do not feel the need to take specific preventive measures against falls.

In chapter 7, we introduced the level of physical activity as nominator in an expression of the Falls Risk by Exposure, the so-called FARE. In this study, falls risk was expressed as the number of fallers per 1000 person-years, a commonly used expression for falls risk, and as the number of fallers per 1000 physically active person-days. Increased difficulty in controlling balance was associated with an increased falls risk per 1000 person-years in a linear fashion, whereas it increased in an exponential manner with the FARE method. Because the FARE method takes into account the risk compensation behaviour of older persons who experience increased difficulty controlling their balance, it is recommended for use in public health policy and research on falls prevention.

In summary, the main observations from the studies described in this thesis are:

1. Older persons perceive their capability to control their balance and the demands that are made on this capability.[4,11]
2. If older persons perceive an increased difficulty in controlling their balance or express fear of falling, they tend to avoid hazards and thereby reduce their physical activity.[12]
3. There are large differences in the level of physical activity among older persons who experience different levels of difficulty in controlling balance (Chapter 7).
4. The level of indoor and outdoor physical activity is related to indoor and outdoor falls, respectively; reducing physical activity reduces the falls incidence per 1000 person-years (Chapters 4, 5).[a,b]
5. Older persons who reduce their physical activity due to perceived difficulties in controlling balance also reduce their exposure to hazards and thereby prevent themselves from falling in the short term (Chapters 4, 5).[a,b]
6. The FARE (the number of fallers per 1000 physically active person-days) increases exponentially in older persons with increasing difficulty in controlling balance compared with the slight and linear increase when falls risk is expressed as the number of fallers per 1000 person-years (Chapter 7).

General conclusion

The following general conclusion can be drawn from the results of the studies described above. Older persons perceive their capability of controlling balance and the demands made on this capability. A general strategy used by older persons to control balance is to reduce physical activity. This appears to be an effective strategy in the short term because it reduces exposure to hazards, thereby limiting the likelihood that a person will fall. Consequently, the level of physical activity as a measure of exposure to hazards is an essential factor that should be included in estimation of the falls risk of older persons.

Methodological considerations

Some aspects of the validity and reliability of the findings related to the importance of the level of physical activity as a measure of exposure to hazards will be addressed.

Validity of the findings

The validity of the findings is supported by the fact that they are based on different studies, and that comparable outcomes were found for indoor and outdoor falls. The level of physical activity appeared to be related to involvement in falls. Reduced levels of physical activity reduced involvement in falls.

In addition, it is of interest to investigate whether the suggested behavioural adaptation of older persons to perceived hazards is also found in other domains, such as participation in traffic. The tendency to withdraw from hazards has been studied extensively among older drivers. In his thesis 'Self regulation of the driving behaviour of older drivers', Baldock[13] reviewed the literature on the involvement of older and younger drivers in crashes. While older drivers (aged over 65) had fewer crashes than younger drivers, they had a higher crash rate per kilometre driven.

The analysis of older driver involvement in traffic accidents addressed a number of driving characteristics. Older drivers travel fewer kilometres per year than younger drivers[14-17] and tend to avoid: driving at night, in inclement weather or busy traffic (high traffic roads, peak hour traffic times), on high-speed roads, in unfamiliar areas or roads, making unprotected turns across traffic or at complex junctions.[13] Thus older drivers are less likely to be involved in a crash occurring during difficult driving conditions, such as during peak hour traffic, darkness, or wet weather than their younger counterparts. This finding is generally thought to reflect the tendency of older drivers to reduce exposure to crash involvement in these difficult driving conditions.[18] It does not indicate that older drivers are better than younger drivers in maintaining control of the driving task during these difficult circumstances. Thus it would seem that older persons tend to withdraw from difficult and demanding situations not only with regard to maintaining their balance control, but also with regard to driving. This finding supports the validity of our findings.

Reliability of the findings

A factor related to the reliability of the findings is the way the level of physical activity is measured. In our studies we used different measures (outdoor walking and cycling, indoor physical activity per 2-hours interval during a day, number of physical active person-days). The application of these various physical activity measures resulted in coherent findings as we considered their association with falls. However, the absence of consensus about a valid and reliable measure of physical activity,[19] limits the reliability of the findings concerning the level of physical activity of persons. This means that we were not able to measure the level of physical activity according to a golden standard, but we could adequately rank persons according to their relative level of physical activity.

Implications of the findings

Before discussing some general implications of the findings, we present a scheme for the process of withdrawal from hazards to control balance (figure 1). The figure illustrates, at the individual level, some age-related general processes that are of relevance for falls prevention. These processes are described in chapter 6, in which the Balance control Difficulty Homeostasis model is presented. Figure 1 illustrates the following age-related processes:

- The level of balance control capability decreases, and its variability increases,[20-24]
- The level of demand on balance control[1] decreases, and consequently its variability decreases because the range of demands becomes narrower,[25]
- The safety margin between the level of balance control capability and the level of balance control demand diminishes,[1,3,4,26,27]
- Three age-related phases of balance control capability and demand can be distinguished, as described below.

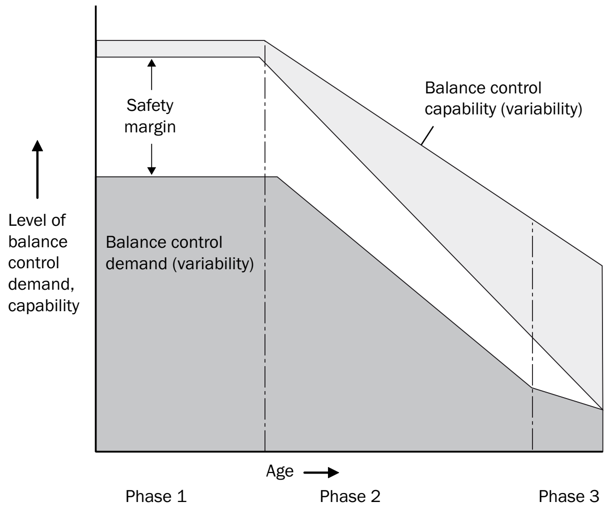

Figure 1 *Schematic representation of hypothesized level of balance control capability of a person and its variability (area), the level of balance control demand and its variability (area), and the difference between them (the safety margin) for three age phases.*

1 The level of balance control demand (>0) that a person is most frequently exposed to during a certain time interval (e.g.: 24 hours): the mode level. A person will also be exposed less frequently to demands at levels higher (or lower) than the mode level. Depending on the level of demand and the concurrent level of balance control capability, a person will (or will not) lose control of balance and fall.

Phase 1

In the first phase, the capability to control balance is high and its variability is low. This means that the balance control system functions at a high level and is highly reliable. This implies that a person can afford to perform physical activities that make low to high demands on the ability to control balance; the variability of demands is high. Performing demanding physical activities successfully increases the capability to control balance because of an exercise effect. The safety margin between the levels of balance control demand and balance control capability is wide, so that there is generally little difficulty controlling balance. Consequently, the probability of falling per 1000 person-years is relatively low. Moreover, the long-term impact of a fall is relatively mild due to the high ability to recover from injury at a younger age.[28-30]

Phase 2

In the second phase, the capability to control balance gradually diminishes as a result of ageing, medication use, chronic disease or lack of physical activity.[31,32] In addition, the hour-to-hour or day-to-day variability in this capability increases because, for example, of an earlier onset of tiredness,[20] the impact of increased use of medication, or postural hypotension. As persons perceive a decrease in their capability to control balance, they tend to compensate for this by avoiding the most demanding physical activities.[33] However, conflicting motives, values, and strong habits inhibit full compensation for the decreased capability to control balance, for instance because persons are expected (and also willing to meet these expectations) to continue to do their daily shopping although it becomes increasingly difficult for them. The compensation process results in a gradual reduction in the variability in balance control demands, because the most demanding physical activities are avoided. Consequently, the safety margin between the capability to control balance and demands made on this capability is reduced. The frequency of performing physical activities associated with an increased difficulty to control balance increases gradually with age, as persons develop difficulties with everyday physical activities like walking or getting out of a chair. As a result, the probability of falling per 1000 person-years increases. Moreover, the long-term impact of a fall becomes more serious due to increasing frailty with ageing, which reduces the ability to recover from injury.[28-30]

Phase 3

In the third phase, the capability to control balance is low and its hour-to-hour or day-to-day variability has become very high. Habitual behavioural patterns, and conflicting motives and values strongly inhibit further compensation for the low capability to control balance because many potentially hazardous physical activities are required for independent living. Consequently, the safety margin between balance control capability and demand is strongly reduced. The frequency of performing physical activities associated with great difficulty in controlling balance is much higher (e.g.: serious difficulty in controlling balance when getting out of bed or chair or walking outside the home for shopping). In combination with the relatively high variability in the capability to control balance, such as might occur due to medication use or postural hypotension, the probability of falling per 1000 person-years is strongly increased. In general, the injuries due to a fall are more serious because of increased frailty (e.g.: increased incidence of fractures), and also because a person's ability to recover is strongly reduced.[28-30]

These general tendencies, as shown in figure 1, illustrate the process at the individual level. However, the process has some important implications for research on risk factors for falls and evaluation of falls prevention interventions at the population level. These implications are addressed below and relate to:

- The identification of risk factors and persons at risk for falls,
- The willingness of older persons to participate in falls prevention interventions,
- The evaluation of falls prevention interventions,
- Public health policy on falls prevention.

- *The identification of risk factors or persons at risk for falls*

As illustrated in phase 2 of figure 1, older persons actually manage to control their balance well, even though their capabilities to do so are substantially reduced.[4,34] Their generally successful behavioural adaptation (reduction of physical activity) to their reduced capability to control balance implies that this capability is strongly reduced as persons start to loose balance control and fall frequently (phase 3). Characteristics of frequent fallers support this assumed process. Frequent fallers per 1000 person-years[35-36] are generally found among persons aged 75 or older[.30] In this age group, often multiple risk factors for falling are identified, including a strongly decreased capability to control balance, and these persons appear to be physically inactive.[30] These studies did however not identify that older persons mask their reduced balance control capability successfully by behavioural adaptation (reducing their level of physical activity).[4,37]

Based on the process as illustrated in figure 1, it is expected that the capability to control balance is already deteriorating before persons start to fall frequently.[34]

Conclusion

Research on risk factors for falls and identifying persons at risk for falling needs to address the decreasing capability to control balance, as illustrated in figure 1, phase 2. In order to establish when this decreasing capability to control balance reaches a critical level, the estimation of the fall risk should include the level of physical activity as a measure of exposure4. For this reason, the FARE, the number of falls or fallers per 1000 physical active days (as described in chapter 7), is recommended as an outcome measure for studies of risk factors and identification of persons at risk of falling.

- *The willingness of older persons to participate in falls prevention interventions*

In general, the willingness of older persons to participate in falls prevention programmes is limited, even among those who have fallen recently.[38-42] Figure 1 suggests that ageing persons are quite successful in controlling their balance by behavioural adaptation during a period in which their capability to control balance is diminishing (phase 2). This might imply that older persons think that they can control or influence their capability to maintain balance. This pattern of coping with reduced balance control is also observed among persons with fear of falling, who generally tend to reduce their level of physical activity.[31,32,43] Thus while older persons consider falls prevention as an important issue, in general (especially as they express their fear) they consider the risk of falling to be highly controllable by behavioural adaptation.[40,44] Many individuals are quite successful in preventing falls, and most do not fall even once a year while performing many activities that require some minimum level of balance control. From research on risk perception and behaviour in other areas, it is known that the perception of being in control is a key predictor of the decision to perform, or to continue to perform, activities that might be relatively harmful.[45]

This relatively successful strategy to control balance[33] might partly explain why older persons reject the idea of participating in falls prevention interventions.[41] Being careful and avoiding danger are the preferred falls prevention strategies;[44] however, in the long term use of these strategies means that while a person's capability of controlling balance is very low, there is little room to reduce physical activity further without compromising independence.

Conclusion

The fact that older persons are generally quite successful in controlling their balance contributes to their reluctance to participate in falls prevention programmes. Most persons at risk of falling might feel that they control their balance quite adequately. This seriously questions the public health impact of the approach of asking persons at risk to participate in falls prevention programmes.

- *The evaluation of falls prevention interventions*

The central issue with regard to the evaluation of falls prevention interventions is the homeostatic nature of the behavioural adaptation persons make in response to their perceived capability to control balance.

When evaluating the effect of falls prevention interventions, it is important to appreciate that if the capability to control balance is improved, older persons tend to increase the demands made on this capability, by becoming more physically active, as described in the BDH model in chapter 6. Consequently, the incidence of falls will probably not be reduced because of the increased exposure to hazards. Potentially successful interventions might be classified as ineffective (no falls reduction) even though they improved the capability to control balance.[46] On the other hand, if one of the effects of a falls prevention intervention is that older persons became more physically inactive, a reduction in falls may be observed which might be the consequence of reduced exposure to hazards (reduced physical activity).[33]

Conclusion

In order to evaluate falls prevention interventions properly, the change in the level of physical activity among participants and controls should be measured. In general, published evaluation studies do not take changes in physical activity into account, which raises doubts about the validity of the conclusions drawn from these studies. Therefore, the newly developed FARE, the number of falls or fallers per 1000 physical active person-days (as described in chapter 7), is recommended as a more appropriate outcome measure for evaluation studies.

- *Public health policy on falls prevention*

The deterioration in the capability to control balance, as shown in figure 1, phase 2, can be regarded as an example of a classical pattern observed in other fields of research on accident prevention, namely, ‘drift into failure’.[47-49] ‘Drift into failure’ is described as a slow, incremental movement of systems operations (for balance control) towards the edge of their safety envelope.[49] ‘Drift into failure’ is hard to recognize because it is about normal people doing normal work (behaving normally), and not about obvious breakdowns or failures. What is perceived as ‘normal’ may be based on what is frequently perceived among older persons: many have difficulty with walking, climbing stairs, or getting up from a chair. These difficulties are frequently observed by older persons themselves (among peers), and also by ‘others’, such as family members, and professionals (welfare workers, general practitioners, medical specialists, designers, politicians). Among older persons and the ‘others’, the perception of ‘normality’ and ‘acceptability’ of the balance control difficulties of older persons may be influenced by the idea that they are quite adequately coping

with these difficulties, because they do not fall often. These ‘others’ are referred to as the ‘system’ that surrounds the individual older person with implicit and explicit opinions, expectations, policies, and demands affecting balance control. From statistics on falls-related injuries, it is becoming increasingly clear that the difficulties in controlling balance experienced by many older persons cause them to ‘drift into failure’, as reflected by the observation that about a third of older persons (65+) fall at least once a year.[21,30]
When addressing the issue of falls prevention policy, a distinction should be made between the older individual who is at risk of falling and the system surrounding the individual. This distinction fits into the two accident prevention approaches described by Reason,[50] namely, the person approach and the system approach, which will be illustrated below.

The person approach
Reason[50] describes the person approach as a widespread and longstanding strategy that is primarily based on the study of risk profiles and the unsafe behaviour of persons who are involved in accidents (falls). The associated countermeasures are mainly directed at reducing unwanted variability in behaviour (restoring balance control) among those who are at risk (older persons at risk of falling). In this approach, persons are viewed as free agents capable of choosing between safe and unsafe modes of behaviour, and therefore the focus is directed towards the persons at risk. A serious weakness of the person approach is that by focussing on the individual origins of accidents (falls), it isolates unsafe acts from their system context. In falls prevention, this approach is seen in attempts to involve older persons in, for example, physical exercise programmes. One of the aims of these programmes is to change an older person’s ‘normal’ pattern of withdrawing from difficult physical activities to a more challenging style of coping with their generally low capability to control balance. Several randomized controlled trials (RCTs) have concluded that this approach can reduce falls,[2,51] but some important difficulties still remain that limit the impact of these programmes on the public health problem. These difficulties are:

1. It appears difficult to replicate the results of the RCT intervention programme in an applied setting.[52,53]
2. The willingness of persons at risk to participate in a falls prevention intervention programme is generally low.[38-42]
3. Interventions are tailored to those with a high falls risk. This approach does not address the source of the problem, the process of a decreasing capability to control balance among many older persons, a process that starts long before individuals are actually at risk of falling.[4,34]

The system approach

According to the system approach,[50] accidents (falls) are seen as consequences having their origins in 'upstream' systemic factors. These upstream systemic factors are factors that might help accidents to happen. For instance, the probability of accidents increases if social pressure or pressure from managers/colleagues forces persons to perform continuously difficult tasks with lack of appropriate devices. These demanding circumstances may be created by decision makers or politicians due to lack of understanding of the full range of (long term) consequences of their policies. These factors might put persons in a situation which provokes mistakes and leading to serious consequences. For instance, if stairs are poorly maintained and handrails are not fixed properly, a slip may result in a breakdown of the handrails (defence) and a serious fall.

The assumption of the systemic approach is that though the human condition cannot adequately be changed, the conditions under which persons are functioning can. In order to change these conditions (building upstream defences), knowledge is required about those processes that have consequences for safety. Actually, building and maintaining these defences should prevent the classical pattern of 'drifting into failure'.[49]

From the perspective of the system approach, the results described in this thesis provide insights into how to develop an upstream defence in relation to falls prevention. A process that contributes to the 'drifting into failure' (falling) of older persons is the pattern of behavioural compensation, which is illustrated in figure 1. This pattern undermines the capability to control balance until compensation is no longer possible due to the high complexity of the balance problems. The suggested defence is to set a standard for the required minimal capability for controlling balance for a given activity.[54] Prevention of falls should focus on measuring and maintaining this required level of capability. In order to establish this defence, healthcare professionals should have access to adequate instruments to measure the capability to control balance and should be informed about possible interventions to maintain and restore this capability. For development and implementation of required instruments, standards and procedures, a political and social commitment to improve the quality (i.e.: balance control) and quantity of physical activity is an important condition. There are some indications which illustrate the current commitment on falls and improving physical activity among older persons. At the European and Dutch political level, falls among older persons is increasingly recognised as an important domain for prevention.[55] The current Dutch policy regarding 'Exercise on receipt' in the healthcare setting[56] is a possible framework for implementing defences against the diminished balance control of older persons. Another approach that may directly or indirectly contribute to falls prevention is the policy to stimulate physical activity among older persons (50+), a campaign from the NISB (NISB www. 30 minuten).[57] This national campaign also stimulates the discussion about the issue of how to increase the level of physical activity among older persons in general, and how to do that safely for older persons with certain chronic diseases or reduced balance control capability.

Conclusion

The person approach to falls prevention has shown its effectiveness in small-scale studies, but its impact at a public health level is still limited.[53] The issue of falls prevention should be primarily oriented to professionals who are involved in the healthcare and welfare of older persons. These professionals should screen for, and if necessary treat, those factors related to emerging balance problems before older people start to reduce their physical activity and in the end lose control of their balance.[54] In addition, environmental modifications made by designers and decisions made by politicians (i.e.: criteria for home-care, funding of research and development) which will affect balance control difficulty among older persons should be systematically identified and alternatives should be offered from the perspective of falls prevention.

Future research

The results of the studies described here have implications for future research.

The identification of risk factors and persons at risk for falls

Research on risk factors for falls should include a measure of exposure in the outcome measure. The FARE is recommended as measure of FAlls Risk by Exposure. Measures of exposure to specific hazards need to be developed further for different populations and environments. For instance, a distinction could be made between the level of participation in indoor and outdoor activities.[58] The development of exposure measures requires the further development and validation of measures of physical activity among older persons.[19]

As was indicated in figure 1, a factor that is assumed to increase the risk of falling is the increased variability in capability to control balance control among persons, which might reduce the estimation of their actual capability to control balance. This variability is generally not taken into account in falls risk research and therefore needs attention.

The willingness of older persons to participate in falls prevention interventions
Research should focus on factors that contribute to involvement of older persons in programmes that enhance balance control capability.

The evaluation of falls prevention interventions
In the evaluation of falls prevention interventions, changes in physical activity need to be addressed in order to control for homeostatic behavioural adaptation due to perceived changes in difficulty in controlling balance among participants. This requires that the level of physical activity be monitored before and after the interventions.

Public health policy on falls prevention
In addition to the evidence-based benefits of the person approach to falls prevention, more research is required to identify elements in the system surrounding older persons that counteract a reduction in falls and injuries. Examples of these system elements are: social norms or opinions about how to deal with balance control difficulties; should one treat balance control problems, or should one reduce physical activity to cope with it. But also professionals in healthcare, architecture or environmental design may contribute to increased falls, for instance: by prescribing medication which reduces balance control, or designing environments which are to demanding for older persons. Finally, important system elements are politicians at the local and national level who will decide on issues which probably do not directly have an impact on falls risk, but whose decisions will contribute to a decrease in the balance control safety margin. Possible relevant policy issues are: public transportation, housing, criteria for home-care, and funding of development of instruments for early detection and treatment of reduced balance control capabilities.
Within each system element, factors should be identified that influence the ratio between capability to control balance and the demands made on this capability. Knowledge about processes and trends in these factors might provide the opportunity for developing ‘upstream’ defences against loss of balance control. As a frame of reference for advocating the need of developing upstream defences, a standard for the minimum required safety margin between balance control capability and balance control demands needs to be established. The development and implementation of such a standard requires innovative research which will contribute to a system which increasingly provides sustainable balance control among older persons for the benefit of public health.

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Chapter 9

Samenvatting

Een valongeval wordt beschouwd als een onverwachte gebeurtenis waarbij de betrokkene neerkomt op de vloer of op een ander lager gelegen niveau. Bij een val verliest een persoon de controle over zijn of haar balans.
Valongevallen vormen bij ouderen een grote bedreiging voor hun gezondheid en zelfredzaamheid. Uit verschillende internationale studies blijkt dat jaarlijks ca. 30% van ouderen (65+) tenminste één keer valt. Als gevolg van een valongeval overlijden in Nederland jaarlijks naar schatting 1.800 ouderen (55+), daarnaast worden 32.000 ouderen in het ziekenhuis opgenomen en 88.000 ouderen op eerste hulp afdelingen van ziekenhuizen behandeld. Naast lichamelijke letsels kunnen valongevallen ook psychologische en sociale gevolgen hebben. Angst om te vallen kan bijvoorbeeld bijdragen aan vergroting van het sociale isolement. Daarnaast hebben ouderen die herhaaldelijk vallen een grote kans op een opname in een verzorgings- of verpleeghuis.
In de literatuur wordt een grote verscheidenheid aan risicofactoren voor vallen bij ouderen genoemd. Drie groepen factoren kunnen worden onderscheiden: gezondheidsfactoren, omgevingsfactoren en gedragsfactoren die de mate van blootstelling (expositie) van personen aan gevaren bepalen.

1. Gezondheidsproblemen vormen de belangrijkste groep risicofactoren, waarbij problemen met mobiliteit (spierkracht, loopvermogen) weer de belangrijkste zijn. Deze en andere gezondheidsproblemen tasten het vermogen van de betrokkenen aan om controle te houden over zijn of haar balans. Dit vermogen wordt de belastbaarheid genoemd.
2. Over de rol van de omgeving als risicofactor voor vallen is nog weinig bekend. Er zijn aanwijzingen dat onvoldoende verlichting, gladde of oneffen vloeren, verkeerd schoeisel en ondeugdelijke loophulpmiddelen de kans op vallen vergroten. Deze, en mogelijk ook andere, omgevingsfactoren kunnen de balans van een persoon verstoren en worden daarom beschouwd als een belasting voor de balans.
3. De derde groep risicofactoren betreft de rol van het gedrag van de personen in kwestie. Naar de rol van gedrag, in het bijzonder de rol van fysieke activiteit, in relatie tot vallen is tot op heden nog geen systematisch onderzoek gedaan. Niettemin wordt aangenomen dat gedrag een essentiële risicofactor voor vallen is. Dit kan als volgt toegelicht worden. Als iemand met grote balansproblemen dagelijks meerdere malen een trap opgaat, dan is de kans op een val relatief groot ten opzichte van een vergelijkbare persoon die het traplopen vermijdt. Bij veel ongevallenonderzoek, zoals in het verkeer, bij sport en bij arbeid, is het gebruikelijk om bij het bepalen van het ongevalsrisico rekening te houden met gedrag van personen waardoor de blootstelling (expositie) aan gevaren tussen personen kan verschillen. Bij valongevallen bij ouderen wordt daarmee tot dusver

geen rekening gehouden, terwijl er tussen ouderen wel grote verschillen bestaan in de mate van fysieke activiteit. Hierdoor kan hun blootstelling aan gevaren sterk variëren.

De doelstelling van dit proefschrift is om het belang te bepalen van fysieke activiteit als een expositiemaat voor het valrisico bij ouderen.

Bij onderzoek naar factoren die een rol spelen bij vallen bij zelfstandig wonende ouderen (65+) is het van belang om valongevallen goed te kunnen registreren.
In hoofdstuk 2 wordt daarom ingegaan op de bruikbaarheid en betrouwbaarheid van een nieuwe manier van registratie van valongevallen. Bij deze methode werden ouderen, die aan het onderzoek meededen, maandelijks door een sprekende computer met stemherkenning opgebeld: de 'Telephone Inquiry System' (TIS). Een telefoonstem vroeg elke persoon, na een korte introductie, of er contact was met de juiste deelnemende persoon. De persoon kon met 'ja' of 'nee' antwoorden. Bij het juiste contact werd door TIS gevraagd of de persoon in de afgelopen maand een valongeval had gehad. Als een persoon een valongeval meldde, dan werd de deze binnen drie dagen teruggebeld voor een persoonlijk telefonisch interview over de toedracht, omstandigheden en gevolgen van de val.
In de twee studies waarin TIS werd geëvalueerd is 48.966 keer contact gezocht met deelnemers. Meer dan 70% van de contacten werd volledig automatisch afgewikkeld. Er was een help-desk ter ondersteuning van dialogen tussen computer en deelnemer die niet goed verliepen. TIS bleek een zeer bruikbaar instrument te zijn voor registratie van valongevallen bij ouderen. De proportie ernstige letsels (fracturen) van het totaal aantal geregistreerde valongevallen bleek vergelijkbaar met die van studies met andere, meer arbeidsintensieve, registratiemethoden. Dit wijst op een voldoende betrouwbaarheid van de registratiegegevens.
Voordelen van TIS zijn verder dat grote groepen deelnemers in korte tijd kunnen worden benaderd door via meerdere telefoonlijnen te laten bellen, en dat elke deelnemer op identieke manier wordt bevraagd.

In hoofdstuk 3 worden de opzet en de resultaten beschreven van een evaluatie van een community interventie om valongevallen bij ouderen (65+) in Sneek te voorkomen. In deze studie namen, naast 1122 zelfstandig wonende ouderen uit Sneek, ook 630 ouderen (65+) uit de gemeenten Harlingen en Heerenveen deel als controlepersonen. De resultaten laten zien dat er na de interventie in Sneek minder vrouwen buitenshuis vielen, in vergelijking tot de vrouwelijke controlepersonen. Bij de interpretatie van de resultaten wordt verondersteld dat de interventie mogelijk tot gevolg heeft gehad dat met name vrouwen na de interventie minder vaak buitenshuis actief zijn geworden in vergelijking tot de controlepersonen. Als gevolg daarvan zouden zij meer tijd binnenshuis doorbrengen waardoor de kans op vallen binnenshuis niet afneemt. Deze interpretatie veronderstelt dat er een relatie is tussen de mate van activiteit in huis en buitenshuis en de kans dat daar gevallen wordt.

In hoofdstuk 4 wordt een onderzoek beschreven naar de relatie tussen de kans op vallen en de mate van fysieke activiteit in huis. Uit dit onderzoek blijkt dat er een sterke samenhang is tussen de kans op vallen en de mate van fysieke activiteit (Spearman correlatie =.89). Op tijdstippen van de dag dat ouderen in huis relatief actief zijn, wordt er ook vaak gevallen. Uit de analyse blijkt bovendien dat de kans op vallen uitgedrukt per aantal fysiek actieve persoonsuren zeer groot is gedurende de nacht (tussen 1 en 6 uur), wanneer ouderen de slaap onderbreken, bijvoorbeeld om het toilet te bezoeken.

In hoofdstuk 5[a] komt de relatie tussen angst om te vallen, de mate van fysieke activiteit buitenshuis en vallenongevallen bij ouderen aan de orde. Op basis van de Task Difficulty Homeostasis Theory (TDHT) werd verondersteld dat ouderen die bang zijn om te vallen, buitenshuis niet vaker vallen dan ouderen die niet bang zijn om te vallen. Aangenomen werd dat ze gevaren buitenshuis vermijden en zo zorgen dat hun kans om te vallen niet toeneemt. De resultaten laten zien dat ouderen die bang zijn om te vallen inderdaad niet vaker vallen tijdens wandelen of fietsen dan ouderen die niet bang zijn. Ouderen die bang zijn om te vallen zijn echter minder vaak buitenshuis fysiek actief (wandelen, fietsen). Ze vallen niet vaker buitenshuis, maar zijn daar ook minder vaak fysiek actief. Wanneer hun kans op buitenshuis vallen wordt uitgedrukt per eenheid fysieke activiteit dan is de valkans wel groter dan voor personen die niet bang zijn om te vallen. De resultaten geven aan dat bij het bepalen van de kans op vallen bij ouderen rekening gehouden moet worden met de mate waarin personen fysiek actief zijn.

In hoofdstuk 5[b] wordt een algemeen causaal model beschreven van de relatie tussen kwetsbaarheid, angst om te vallen, mate van fysieke activiteit en vallen bij ouderen. Toenemende kwetsbaarheid bij ouderen verhoogt de kans op vallen, maar ook de mate van angst om te vallen. Vanuit angst om te vallen worden twee causale paden verondersteld die de kans op vallen in tegengestelde richting beïnvloeden. Het eerste pad loopt van toenemende angst om te vallen naar toenemende onzekerheid bij het bewegen, wat de kans op vallen vergroot. Het tweede pad loopt van angst om te vallen naar het verminderen van fysieke activiteit (vermijden van gevaren), wat de kans op vallen verkleint. Omdat er twee tegengesteld gerichte causale paden worden verondersteld tussen angst om te vallen en de kans op vallen, wordt de richting van de causale relatie bepaald door de resultante van de twee tegengesteld gerichte causale paden. Geconcludeerd wordt dat er sprake is van inconsistente mediatie tussen angst om te vallen en de kans op vallen.

In hoofdstuk 6 wordt een beschrijving gegeven van het 'Balance control Difficulty Homeostasis model' voor vallen bij ouderen (BDH model).
In het BDH model wordt ervan uitgegaan dat personen ernaar streven om controle over hun balans te behouden. Personen hebben controle over hun balans zolang als hun vermogen om hun balans te bewaren (belastbaarheid) groter is dan de belasting die vanuit de omgeving komt.
Het BHD model beschrijft een homeostatisch mechanisme volgens welke personen ernaar streven om een geprefereerde veiligheidsmarge te behouden tussen het door henzelf waargenomen vermogen om hun balans te bewaren (waargenomen belastbaarheid), en de door de persoon waargenomen belasting die vanuit de omgeving inwerkt op die belastbaarheid.
Volgens het model passen personen hun gedrag aan, en vermijden ze gevaarlijke situaties, als ze vinden dat de belasting op het vermogen om hun balans te bewaren onacceptabel dicht in de buurt komt van hun belastbaarheid. Het belangrijkste criterium voor gedragsaanpassing is volgens het model niet hun ingeschatte kans op vallen, maar de mate waarin ze de moeite die ze ervaren om controle over hun balans te bewaren acceptabel vinden. Een gedragsaanpassing die in dit kader samenhangt met toenemende moeite met lopen is dat oudere personen minder fysiek actief worden (minder vaak en lang gaan lopen). Door minder fysiek actief te worden, blijken ouderen met toenemende balansproblemen te voorkomen dat ze vaker gaan vallen; ze compenseren via hun gedrag voor toenemende moeite met balanscontrole.
Het model suggereert dat de kans op vallen bij ouderen toeneemt als ze door omstandigheden een kleinere veiligheidsmarge accepteren (frequent moeten traplopen in eigen huis ondanks moeite daarmee), of als ouderen minder goed in staat zijn om hun eigen belastbaarheid en/of de belasting uit de omgeving op hun balanscontrole waar te nemen (bijvoorbeeld bij cognitieve achteruitgang). In beide gevallen zullen ouderen niet geneigd zijn om zelf maatregelen te nemen om vallen te voorkomen.

De kans op vallen bij ouderen wordt in de literatuur gebruikelijk uitgedrukt als het aantal vallers per 1000 persoonsjaren. In deze maat wordt geen rekening gehouden met verschillen in de mate waarin ouderen fysiek actief zijn. De mate van fysieke activiteit wordt opgevat als een maat voor blootstelling (expositie) aan gevaren voor vallen. In hoofdstuk 7 wordt de gebruikelijke maat vergeleken met een maat waarin

de kans op vallen wordt uitgedrukt in het aantal vallers per 1000 fysiek actieve persoonsdagen; de FARE (FAlls Risk by Exposure).
Er is een vragenlijstonderzoek uitgevoerd onder 771 zelfstandig wonende ouderen (71+). Daaruit bleek dat ouderen met grote moeite met balanscontrole minder fysiek actief waren dan ouderen die daar minder moeite mee hadden. De kans op vallen, uitgedrukt per 1000 persoonsjaren, nam lineair toe met toenemende moeite met balanscontrole. De kans op vallen uitgedrukt met de FARE, bleek echter exponentieel toe te nemen. De FARE houdt rekening met het feit dat ouderen zelf via hun gedrag compenseren voor de toenemende moeite die ze hebben om controle over hun balans te bewaren. Daarom wordt de FARE aanbevolen als maat om de kans op vallen uit te drukken.

In hoofdstuk 8 worden de belangrijkste waarnemingen en conclusies uit de voorgaande hoofdstukken samengevat en worden de implicaties beschreven.
De belangrijkste observaties zijn:

1 Ouderen nemen zelf waar wat hun vermogen is om controle over hun balans te behouden (belastbaarheid) en ook de mate van belasting daarop vanuit de omgeving.
2 Als ouderen een toenemende moeite ervaren met hun balanscontrole, of bang zijn om te vallen, dan zijn ze geneigd om expositie aan gevaren te vermijden en minder fysiek actief te worden.
3 Er zijn grote verschillen in de mate van fysieke activiteit tussen ouderen.
4 De mate waarin ouderen binnenshuis en buitenshuis fysiek actief zijn is gerelateerd aan de kans dat ze binnen of buiten vallen; verminderde fysieke activiteit vermindert de kans op vallen per 1000 persoonsjaren.
5 Ouderen met toenemende moeite met balanscontrole die tevens fysiek inactiever worden, verminderen hun blootstelling (expositie) aan gevaren en voorkomen zo op korte termijn dat ze vaker gaan vallen.
6 De valkans uitgedrukt in de FARE neemt exponentieel toe met toenemende moeite met balanscontrole vergeleken met een geringe lineaire toename van de valkans als deze wordt uitgedrukt in aantal vallers per 1000 persoonsjaren.

Voor vier terreinen worden de implicaties aangegeven van de observaties uit de voorgaande hoofdstukken.

1 *Het identificeren van risicofactoren of personen met verhoogde kans op vallen.*
Op dit terrein wordt het van groot belang geacht dat de FARE wordt toegepast. Een belangrijk argument daarvoor is dat ouderen in hun gedrag compenseren voor

toenemende moeite met balanscontrole. Zij gaan gevaren vermijden (afnemende expositie) en maskeren zo hun problemen met de balanscontrole. Risicofactoren voor verminderde balanscontrole komen onvoldoende in beeld als geen rekening wordt gehouden met verschillen in expositie.

2 *De bereidheid van ouderen om deel te nemen aan valpreventie interventies.*
Ouderen (65+) verliezen in het algemeen slechts een enkele keer per jaar de controle over hun balans, veruit de meeste tijd behouden ze hun balanscontrole, mede door in hun gedrag rekening te houden met hun belastbaarheid. Vanuit dit gezichtspunt kan worden ingezien dat de bereidheid van ouderen om deel te nemen aan valpreventie interventies gering is. De geringe participatie van ouderen in valpreventie programma's beperkt de mate waarin deze op landelijk niveau kunnen bijdragen aan vermindering van de valproblematiek.

3 *Het evalueren van valpreventie interventies.*
Op dit terrein wordt het van groot belang geacht dat de FARE wordt toegepast. Als bij een interventieprogramma gericht op valpreventie de belastbaarheid van ouderen toeneemt, dan zullen ze geneigd zijn om fysiek actiever te worden, met als gevolg een hogere expositie. Dat kan weer tot gevolg hebben dat het aantal valongevallen niet verandert. Ten onrechte zou dan de conclusie kunnen zijn dat de interventie niet effectief is geweest om de kans op vallen te reduceren. Door rekening te houden met verschillen in mate van fysieke activiteit kan een scherper beeld worden verkregen van de effectiviteit van de interventie.

4 *Volksgezondheidsbeleid voor valpreventie bij ouderen.*
Het volksgezondheidsbeleid ten aan zien van valpreventie moet zich sterker gaan richten op het door professionele zorgverleners vroeg signaleren en behandelen van balanscontrole problemen bij ouderen in plaats van de aandacht te richten op personen die (herhaaldelijk) vallen.

Toekomstig onderzoek

In het kader van de bovengenoemde terreinen wordt versterking van de volgende onderzoeksrichtingen bepleit:

1 Verdere ontwikkeling van expositie maten; de ontwikkeling en validering van maten voor fysieke activiteit bij ouderen;
2 Bij onderzoek naar valrisico's meer aandacht besteden aan de variabiliteit van de belastbaarheid van personen in de tijd (bijvoorbeeld: gedurende een dag, of nadat een persoon een zekere inspanning heeft verricht).

3 Onderzoek naar mogelijkheden om te bevorderen dat ouderen deelnemen aan programma's die gericht zijn op verbetering van hun balanscontrole.
4 Bij evaluatie van valpreventie interventies de mate van fysieke activiteit monitoren en in de analyse betrekken als expositiemaat.
5 Bepalen van de rol van personen in de omgeving van ouderen die de kans op vallen kunnen beïnvloeden. Bijvoorbeeld: opinies van partner en vrienden en het handelen van professionals (thuiszorg, huisarts, fysio/ergotherapeut) die invloed hebben op het omgaan met verminderde balanscontrole (trainen, of moeilijke situaties vermijden). Verder kan gedacht worden aan beleidsmakers die besluiten nemen over bijvoorbeeld de inrichting van de woonomgeving, transportsystemen, en over het ontvangen van thuiszorg.
6 Ontwikkelen van een instrument om vroegtijdig het verlies van balanscontrole te signaleren waarbij een standaard is opgenomen voor de minimaal noodzakelijke veiligheidsmarge tussen belasting en belastbaarheid.

Curriculum Vitae

Gert Jan Wijlhuizen is geboren op 29 oktober 1960 in Den Haag. Na het afronden van het VWO aan de Christelijke Scholengemeenschap Zandvliet in Den Haag in 1979, is hij Psychologie gaan studeren aan de Faculteit Sociale Wetenschappen van de Universiteit Leiden. In 1988 is hij daar afgestudeerd in de Psychologische Functieleer met als afstudeeronderwerp: het inschatten door professionals en leken van de gevaarlijkheid van verkeerssituaties. In 1988 is hij als onderzoeker gaan werken bij het Nederlands Instituut voor Praeventieve Gezondheidszorg (NIPG-TNO), het huidige TNO Kwaliteit van Leven. Hij heeft daar deelgenomen aan verschillende onderzoeksprojecten, met name op het terrein van letselpreventie bij ouderen (vallen) en, gevolgen van, verkeersongevallen.

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Wolfgang Pauli and Niels Bohr
studying a Tippe Top

PHYSICAL ACTIVITY AND FALLS IN OLDER PERSONS

Gert Jan Wijlhuizen