ORIGINAL ARTICLE

EXERCISE AND RISK OF INJURIOUS FALL IN HOME-DWELLING ELDERLY

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ABSTRACT

Objectives. To examine the relationship between different types of physical exercise and the risk of subsequent fall-related injury.

Study Design. A prospective study of the home-dwelling elderly.

Methods. A population sample of home-dwelling subjects aged 85 years or older (n=512) in northern Finland participated in the study. Baseline data were collected by home-nursing staff through postal questionnaires and clinical tests. Frequency and times of physical exercise – that is, walking exercise and other exercise (home exercise, group exercise, gardening, cross-country skiing, dancing, swimming, bicycling) – and falls were recorded by a nurse examiner, who telephoned the participants 8 times during a 2-year follow-up period. Statistical analyses were based on Cox regressions and pooled logistic regressions.

Results. The risk of injury-causing falls was reduced by other exercise taken at least 1 hour per week compared with corresponding non-exercise; adjusted odds ratio 0.37 (0.19–0.72) but not by walking exercise. The risk of injury-causing falls was not increased by any kind or amount of exercise taken. Female sex, a history of recent fall-related injury and poor baseline near-vision acuity were the other significant predictors of injury-causing falls.

Conclusions. Habitual physical exercise proved to be safe and some of the exercises were associated with reduced risk of subsequent fall-related injury. Female sex, an injury-causing fall in the recent past and problems with near vision increased the risk.

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Keywords: fall, accidental fall, injury, ageing, physical activity, exercise
INTRODUCTION

Injury-causing falls are the most serious and frequent home accidents among the elderly. Falls cause major concerns for health and social care providers and clients, as the elderly are growing in number with the rapid increase in life expectancy among the general population (1), but also independently of this demographic change (2,3). The ”oldest old” are the fastest growing section of most western populations. Twenty to thirty percent of those who fall sustain injuries that increase the risk of reduced mobility, loss of independence and premature death (4). Fall-related injuries often lead to a reduction of habitual physical and social activities (5), and they are a major reason for admission into hospital or residential care (6).

Prospective studies among the home-dwelling elderly have shown that female sex, older age, balance disorders, cognitive impairment, neuropathic disorders, muscle weakness and use of long-acting benzodiazepine drugs (5,7–9) are general risk factors for injury-causing falls. The roles of these risk factors, however, have differed markedly between the different studies (10). For example, the time of day (11,12), gender (13), functional ability (13), fall situations, behaviour and physical activity (7,14,15) may contribute to the probability of sustaining fall-related injuries.

The relationship between physical activity and injurious falls is complex. Observational studies show that behavioural or situational states characterized by low levels of physical activity (7) or, alternatively, high levels of physical activity may increase the risk of falling injuries (7,14–16) and fractures (17). On the one hand, frequent engagement in rapid or forceful activities is associated with fall-related injuries (7,14,18). On the other hand, low levels of recreational physical activities are associated with subsequent injury-causing falls (19). A recent decline in heavy outdoor work activity is associated with subsequent fall-related fractures but not major soft-tissue injuries (20).

Evidence about preventability of falling injuries by exercise is minor. Post-hoc analyses of 4 randomized falls prevention trials showed that strength and balance exercises in standing positions delivered by a physiotherapist and trained nurses may reduce the risk of injury-causing falls by 35%, most effectively among those aged 80 or older (21). Multifactorial non-randomized interventions using a “population approach” have reduced fall-related injuries by 6%-33% in elderly populations (22).

In order to elucidate the relationship between physical exercise and the risk of injury-causing falls among elderly home-dwellers, we conducted a population-based study that took into account the kind and timely variability of exercise.

MATERIAL AND METHODS

Study participants

The target population consisted of 827 home-dwelling person aged 85 years or older living in the city of Oulu, at 65° northern latitude, in northern Finland, on 30 August 2000, according to the official population register and the local geriatric registers. Altogether, 555 persons (126 men, 429 women) participated in the baseline examinations between 26 October 2000 and 26 March 2001. The sample and the process of recording falls and fall-related injuries have been described in detail in a previous paper (12). From 11 April to 31 May 2001
and onwards, 512 persons participated in the prospective recording of physical exercise and falls (Fig. 1). From 3 September 2001 to 14 February 2002, 217 intervention subjects and 220 controls were randomly selected to participate in a 16-month pragmatic intervention. Altogether, 136 subjects received recommendations composed of walking exercise, home exercise, group exercise or self-care exercise. Compliance with these interventions was low, however, and there was no increase in the frequency of home exercisers or those engaged in walking and group exercise. The intervention had no statistically significant effects on the risk of fall-related injuries (23).

**Baseline examinations**

The study protocol was approved by the institutional ethics committee, and informed consent was obtained before interviewing the participants. Movement ability was characterized by a question concerning the ability to move outdoors (without difficulty, with some difficulty, with great difficulty, unable without personal assistance, fully unable), and the variable was categorized as great difficulty or worse versus some difficulty or better. Trouble with vision when moving (yes/no) and trouble with near vision (e.g., while reading or knitting) were assessed according to Leinonen et al. (24). Mood was assessed according to the short version of the Geriatric Depression Scale, and if the subject's sum score was 7 or more, he/she was regarded as being depressed (25).
Home-nursing staff measured cognition with the Mini Mental State Examination test (MMSE, 0-30) (26). Cognition was classified as poor if the subject’s sum score was less than 21 points (27) or if she/he was taking medication for dementia. Diabetes requiring medication was recorded from the subject’s personal health insurance card, and medication was recorded from all available data present at home (drug packages, drug prescriptions). Grip strength was measured by the Jamar Hydraulic Hand Dynamometer (Trent Building, South Buckout St., Irvington, NY 10533 USA). Body mass index was calculated from measured weight versus squared height in light clothing kg/m², by categorizing the values in a standard way into <18.5, 18.5<25, 25<30, ≥30. Systolic blood pressure (mm Hg) was measured twice, at a 10-minute interval, with a mercury manometer with the subject in a sitting position. Blood pressure was defined as the mean value of the 2 measurements. Low systolic blood pressure was defined as less than 120 mmHg (28).

Standing balance was assessed with the feet in tandem, semi-tandem and side-by-side positions. Those unable to hold a semi-tandem position for 10 seconds were evaluated with the feet in a side-by-side position. Those able to hold the semi-tandem position were further assessed with the feet in a tandem position, and the time up to 10 seconds maintained in this position was recorded. Walking speed was based on seconds to cover a 2.4-meter distance, irrespective of whether or not a walking device was being used. Ability to rise up from a chair included 5 iterations without using one’s arms, and the time required to do this was recorded. Categories of performance were set up for each of the 3 performance measures, and finally, a sum score of all 3 performances (0-12) was calculated according to Guralnik et al. (29).

Phone call follow-up
The first round of phone calls was done approximately 2 months after the baseline examinations by a nurse examiner working at the university (12). The participants had altogether 8 phone-call rounds. The physical exercise done by each subject during the preceding 2 weeks was elicited by using a structured form. Subjects were considered to have engaged in physical exercise if they answered “yes” to the following question, “Did you do walking exercise (ordinary walking during the daily activities, including shopping) or other exercise (home exercise, gardening, cross-country skiing, dancing, swimming, bicycling, group exercise) during the past 2 weeks?” If so, the frequency (times) and approximate duration (minutes) were determined by asking an open-ended question (24). The amounts of reported walking exercise and other exercise during the previous 2 weeks were first calculated for the entire follow-up period. Using these data, the amounts of exercise were stratified and presented for 1 week’s time. Walking exercise was stratified into quartiles of the population; none, <60 minutes, 60<140 minutes and ≥140 minutes. Other exercises were categorized into none, <60 minutes and ≥60 minutes during a week. Self-rated health (very good, good, average, poor, very poor) were asked according to a structured protocol.

A fall was defined as an unexpected event where a person fell to the ground from an upper level or from the same level (30). Fall-related injuries included major soft-tissue injuries (wounds needing suturing, disloca-
tions or more severe injuries) and fractures (5,11). Medical records of all participants in the health centre of Oulu and the local hospital were examined at the end of follow-up to check for injury-causing falls. Recordings were continued from the day of the first phone call until the end of follow-up, admission into long-term institutional care, death or refusal from recording (12).

Statistical analysis
Person time and the number of injury-causing falls were first prospectively calculated from each phoning day until the following phoning day in the different exercise activity categories, after which the incidence rates (IR) were pooled. IR was calculated as per-person year (PY) (31).

Primarily to be used in the characterization and the adjusted analyses, the baseline risk factors of subsequent injury-causing falls between the baseline and the end of follow-up were analysed using Cox regression. The proportional hazards assumptions were tested by constructing interaction terms between each variables and time to end-point.

Pooled logistic regression analysis (7,32), which is an analytic method equivalent to the time-dependent proportional hazards model applied to repeated events, was done to examine the risk of injurious falls. In these analyses, each 2-month follow-up period was assumed to represent an independent period of observation, and an incident injury-causing fall was a dependent variable in each period. Multivariate models were adjusted for self-rated health (good/average/poor) at the time of exercise, using average health as non-exposed, the occurrence of an injury-causing fall (yes/no) during the preceding phone-call round, the phone-call round number (1-8), having received recommendations in connection with the pragmatic intervention (yes/no), age (years) at baseline and gender (female/male) along with the variables that were, according to the Cox regression models, significantly associated with injury-causing falls. All statistical analyses were performed using SAS version 8.2 (SAS Institute Inc., Cary, NC). P-values were 2-sided, and p-values of less than 0.05 were considered statistically significant.

RESULTS
The average age of both men and women at baseline was 88 (SD 2.6) years. Sixty-nine percent of the participants used some mobility device. The baseline risk factors of injurious falling are presented in Table I. Female sex, great difficulty in walking outdoors, low systolic blood pressure, dementia, trouble with near vision, depression, lower body mass index, medically treated diabetes mellitus, lower score for lower extremity performance, lower grip strength and higher number of medications were significantly associated with injury-causing falls according to univariate Cox regression analyses. These variables, along with higher age, were entered in a multivariate Cox regression analysis to see the independent associates of injurious falling. Female sex; 2.08 (1.19–3.57), lower score for lower extremity performance; 1.07 (1.00–1.13), higher body mass index; 0.65 (0.50–0.84), and trouble with near vision; 1.59 (1.08–2.35) were the significant associates.-

The overall IR of injury-causing falls was 0.15 per PY. Within each exercise group, IR tended to decrease as exercise activity
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Table I. Baseline risk factors of fall-related injuries according to Cox regression analyses.

| Risk factor                                      | With injury | Without injury | p<sup>a</sup> |
|-------------------------------------------------|-------------|----------------|--------------|
| Female, n (%)                                    | 98 (87)     | 297 (74)       | <0.01        |
| Great difficulty in walking outdoors, n (%)      | 26 (23)     | 74 (19)        | <0.01        |
| Systolic blood pressure <120 mmHg, n (%)         | 11 (10)     | 29 (8)         | 0.04         |
| Mini Mental State Examination test <20 points, or use of dementia medicine, n (%) | 24 (22)     | 79 (20)        | 0.01         |
| Trouble with vision when moving, n (%)           | 26 (23)     | 76 (19)        | 0.35         |
| Trouble with near vision, n (%)                  | 59 (54)     | 157 (40)       | 0.01         |
| Short Geriatric Depression scale >7 points, n (%)| 24 (22)     | 79 (20)        | 0.02         |
| Body mass index, kg/m<sup>2</sup>, n (%)         |             |                | <0.01        |

<18.5
18.5<25
25<30
≥30
Medically treated diabetes mellitus, n (%) | 10 (9) | 37 (9) | 0.04 |
Use of hypnotic medicine, n (%) | 35 (31) | 116 (29) | 0.26 |
Use of anxiolytic medicine, n (%) | 7 (6) | 40 (10) | 0.63 |
Baseline age, years, mean±SD | 88 (2.5) | 88 (2.6) | 0.06 |
Lower extremity performance score<sup>b</sup>, mean±SD | 5.2 (3.3) | 5.7 (3.3) | <0.01 |
Grip strength (kg), mean±SD | 18 (9.1) | 22 (13) | <0.01 |
Number of medications, mean±SD | 6.7 (4.4) | 5.5 (3.6) | <0.01 |

<sup>a</sup> p is from Cox regression, for yes/no (dichotomized) and for one unit change (ordinal or continuous) variables.
<sup>b</sup> Sum score (0-12) is calculated from balance, walking speed and chair stand scores.

Table II. Incidence rates (N/PY<sup>a</sup>) of injury-causing falls by quantity levels of different physical exercises.

| Physical exercise | Minutes/week | PY | Falls (n) | Falls/PY |
|-------------------|--------------|----|-----------|----------|
| Walking exercise  |              |    |           |          |
| none              | 234          | 40 | 0.17      |          |
| 1–59              | 176          | 25 | 0.14      |          |
| 60–140            | 240          | 34 | 0.14      |          |
| >140              | 216          | 28 | 0.13      |          |
| Other exercise<sup>b</sup> |            |    |           |          |
| none              | 565          | 100| 0.17      |          |
| 1–59              | 135          | 13 | 0.10      |          |
| >60               | 166          | 14 | 0.09      |          |
| Total             | 866          | 127| 0.15      |          |

<sup>a</sup>PY is person year.
<sup>b</sup>Home exercise, gardening, group exercise, cross-country skiing, dancing, swimming, bicycling.

increased; walking exercise 0.17, 0.14, 0.14, 0.13, and other exercise 0.17, 0.10 and 0.09, respectively (Table II).

The unadjusted and adjusted results of the pooled logistic regression analyses for injury-causing falls as regards walking exercise and other exercise are presented in Table III. The risk of injury-causing falls was not reduced as regards walking exercise, but it was reduced as regards other exercise taken ≥60 minutes a week as compared with no exercising; 0.37 (0.19–0.72). Other exercise taken <60 tended to be associated with reduced risk of injury-causing falls; 0.56 (0.30–1.04).
The other statistically significant variables for injury-causing falls in the adjusted model of other exercise were the occurrence of an injury-causing fall during the preceding phone-call round 2.50 (1.20–5.20), female sex 1.79 (1.02–3.14) and poor near-vision acuity 1.63 (1.12–2.39).

### DISCUSSION

This population-based study among the home-dwelling elderly showed that the risk of injury-causing falls was reduced by exercise other than walking when taken as part of everyday life compared with no exercise at all.

Some studies suggest a U-shaped association between the level of physical activity and injury-causing falls, showing that the least active and the most active people carry the highest risk (7,8,33). This reveals the complex relationship between the host, the activity and the risk of fall-related injuries. Taking into account these complexities, the present study found that, on an average, walking exercise and other exercise were safe among the home-dwelling elderly population. Even more importantly, other exercise was associated with a reduced risk of injury-causing falls, and there was a suggestion of a dose-response between increasing activity and reduced risk (34).

Based on the results of this study, we cannot make statements about the benefits or disadvantages of novel exercise programs prescribed for elderly subjects. Moreover, the type of effective exercise could not be described in detail. Despite these limitations, our observations lend credibility to the findings of the intervention studies that have shown reduced risk of fall-related injuries by supervised home-based strength and balance exercises (21).

The current secondary findings suggest that interventions to prevent fall-related injuries among the elderly population should be targeted to women, those with a history of a falling injury in the recent past and those near-vision problems. Treatment of osteoporosis (35), educational and environmental modifications based on the

| Physical activity | Minutes per week | Unadjusted Odds ratio (95%CI) | Adjusted* Odds ratio (95%CI) |
|-------------------|------------------|-----------------------------|-----------------------------|
| Walking exercise  |                  |                             |                             |
| none              | 1.00 (reference) |                             |                             |
| <60               | 0.82 (0.48–1.38) | 0.87 (0.50–1.50)            |                             |
| 60–140            | 0.81 (0.50–1.31) | 0.94 (0.56–1.58)            |                             |
| >140              | 0.63 (0.38–1.07) | 0.83 (0.46–1.48)            |                             |
| Other exercise    |                  |                             |                             |
| none              | 1.00 (reference) |                             |                             |
| <60               | 0.50 (0.27–0.91) | 0.56 (0.30–1.04)            |                             |
| >60               | 0.40 (0.22–0.74) | 0.37 (0.19–0.72)            |                             |

*Adjusted for self-rated health at the time of exercise (poor/average/good), phone-call round number (1–8), injury-causing fall during the preceding phone-call round (yes/no), having received recommendations for exercise in a pragmatic intervention (yes/no), age at baseline (years), gender (female/male), body mass index (<18.5/18.5–25/<30/≥30 kg/m2), trouble with near vision (yes/no), lower extremity performance score (0–12).

bHome exercise, group exercise, gardening, cross-country skiing, dancing, swimming, bicycling.
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Situational and behavioural factors related to falling injuries (8) and environmental safety modifications aimed to reduce the risks associated with poor vision (36) might be useful interventions in these situations.

One strength of the present study is the modestly representative population sample of the home-dwelling elderly (12). The data were collected on several occasions and from several sources, raising the possibility of bias. In particular, the validity of phone interviews in the measurement of exercise activity among those with impaired cognition is questionable, although this questionnaire was adopted from another large population-based study in Finland (24). In the present study, relatives and home-nursing staff helped in these interviews when needed. Although we did not use diary reporting in recording the falls (31), the validity of recording the major fall-related injuries was obviously high because we reviewed the hospital and health centre records. Regrettably, the validity of self-reported recordings of fall injuries was not evaluated. One study has suggested that the validity of self-reported fall events is higher for falls that result in injury than those without an injury (37). We do not believe that registration bias distorted our results. A nurse recorder collected the data in telephone interviews that were done according to a structured form, and she was unaware of the hypothesis of the present study. A pragmatic randomized intervention was carried and could have caused the effect that was found. However, adherence was low, and accordingly, intervention effect was unlikely. Effects of exercise could have been influenced by a regression to the mean effect. Generally, those who exercise the least are thought to benefit the most from exercising, but regression to the mean may explain most of this effect. Repeat measurements are one way to avoid bias related to the regression to the mean effect (38). Exercise activity was questioned 8 times in the present study, which lessens this effect. Furthermore, the subjects’ health status did not, at large, confound the results, because a large number of baseline covariates, along with contemporary self-rated health, were controlled for in the analyses. Nevertheless, further studies with larger samples are needed to examine the relationships between the different types and quantities of physical exercise and the risk of fall-related fractures. More importantly, randomized controlled trials are needed to examine the effect of novel exercise being prescribed for older adults (39).

In conclusion, this study showed that habitual exercise other than walking conducted as part of everyday life is associated with a reduced risk of fall-related injuries, while female gender, fall-related injuries in the recent past and problems with near-vision acuity seem to increase the risk. The effect of novel types of exercise on the fall-related injury risk among the elderly remains to be shown.

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