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ORIGINAL ARTICLE

Characteristics of fallers who later sustain a hip fracture: a NOREPOS study

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Abstract

Summary Fall prevention programs have shown inconclusive results concerning hip fracture reduction. We found that fallers with poor health, low societal participation, and use of psychotropics/painkillers had a threefold to fivefold increased hip fracture risk compared to non-fallers without these risk factors. This may help target fall prevention towards high-risk individuals.

Introduction To investigate whether self-reported information on health, societal participation, and drug use in older people, easily obtainable by health care providers, contribute to predict future hip fracture beyond self-reported falls.

Methods We used data from 3801 women and 6439 men aged 70–79 years participating in population-based studies in five counties in Norway 2000–2003. Height and weight were measured. Socioeconomic status, lifestyle, health status, and history of falling were self-reported through questionnaires. Falls last year were dichotomized into one or more versus no falls. Hip fractures were identified by linkage to hospital data with follow-up through 2013. Hazard ratios (HR) with 95% confidence intervals (95% CI) for hip fracture by combinations of risk factors with history of falling were estimated using Cox proportional hazards regression.

Results More women (32.4%) than men (27.7%) reported one or more falls during the previous year, and 17.9% of women ($n=682$) and 8.9% of men ($n=572$) suffered a hip fracture during median 11.6 years of follow-up. Poor health, low societal participation, and use of psychotropics/analgesics among fallers were strong predictors of hip fracture. The presence of all three risk factors and history of falling was associated with HR 2.92 (95% CI 2.10–4.05) for hip fracture in women and HR 4.60 (95% CI 2.71–7.81) in men compared to non-fallers without these factors.

Conclusion Our study indicates that self-assessment of health, information about activities outside home, and drug use among fallers far better identify high risk of hip fracture in older people than information about falls alone.

Keywords Fall · Hip fracture · Prediction · Risk factor

Introduction

Fall injuries in the senior population are a major health hazard. Serious fall injuries like hip fractures are often life-changing and lead to loss of independence [1], reduced life expectancy [2], and high costs to society [3, 4]. According to the Global Burden of Disease framework, fall injuries in persons aged 75 years and older rank as the 9th leading cause of death and the third leading cause of disability-adjusted life-years (DALYs) in Norway [5].

Fall intervention initiatives are an important part of community health care, and increasingly important with an aging population. Both fall prevention programs and pharmacological osteoporosis treatment seek to reduce the risk of fractures. For prevention purposes, it seems reasonable

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to combine these approaches. However, while treatment of osteoporosis in those with previous fractures and/or very low bone mineral density has shown to reduce fracture risk [6], fall prevention programs that effectively prevent falls are largely inconclusive in terms of hip fracture prevention [7, 8]. Because substantial resources are poured into fall prevention initiatives, there is a need to critically evaluate the effectiveness of these initiatives. One possible reason for the inconclusive results concerning reduction in incidence of hip fracture could be that fallers with a particularly high risk for a future fracture are not often targeted in the interventions.

More than a third of elderly aged 65 years and older fall at least once a year [9]. Since most falls do not result in a fracture [10], there must be modifying factors connected to the individual, the living situation, or the environment that contribute to determine the outcome of a fall. The aim of this study was to explore the extent to which self-perceived health, participation in society, functional abilities, and use of different medications like psychotropics and analgesics as well as antihypertensives contribute, independently and in combination, to predict future hip fracture beyond self-reported falls.

Material and methods

The Five Counties Study

The Five Counties Study [11], which is part of Cohort Norway [12], is a collection of harmonized data from population-based multi-purpose regional health studies in five counties in Norway. The counties are located in different parts of the country and contain both urban and rural citizens [11, 13, 14]. All studies included a basic physical examination collecting measures of height and weight, following a common standard protocol. In all studies, the participants filled in questionnaires with a common core of questions concerning socioeconomic factors, lifestyle, health, diseases, and drug use.

All men and women in pre-specified birth cohorts were invited to participate. The design and procedure of the health studies and the main questionnaire were similar in all five counties [13]. Since one of the sub-studies was a follow-up to a previous study in men only [15], men comprised the majority of our study population.

In this paper, we have restricted the sample to participants aged 70–79 years old at the health examination. This group filled in a version of the main questionnaire that included questions particularly tailored to the elderly population concerning falls, social participation, and functional ability. All information on exposure variables and covariates was collected at baseline (2000–2003). The attendance rate was 52.5% in women and 50.9% in men aged 70–79 years, but varied somewhat between counties. In this paper, we have included 10,240 individuals (3801 women and 6439 men) who answered questions about falls and smoking, and had available data on age, hip fracture, and measured height and weight, comprising 99.3% of the participants in the selected age span.

Exposure variables

The participants were asked whether they had experienced a fall during the previous year, with the response options "No," "Yes 1–2 times," and "Yes, more than 2 times". Since a relatively low proportion responded to have fallen more than 2 times (6.1%), the variable "history of falling" was dichotomized into no falls last year versus one or more falls last year.

Available variables previously shown to be confounders in the association between falls and hip fracture were considered for inclusion. These include *marital status* (dichotomized into married/partner vs. unmarried/divorced/separated/widowed), *age* (years), *height* (cm), *body mass index* (*BMI*) defined as weight in kg divided by height in meter squared (m^2), *length of education* (years), *leisure time physical activity* (two questions about number of hours with light or vigorous physical activity per week summarized (range 1–8) and used as continuous variable), *smoking* (dichotomized into current daily yes/no), *self-perceived health* (four levels, dichotomized into poor/not very good vs. good/very good), and *one or more chronic diseases*: We used answers to the question "Do you have or have you had: *Myocardial infarction*, *angina pectoris*, *stroke*, *diabetes*, *asthma* (*yes/no*)". These answers were summarized into a disease score (range 0–5) dichotomized into no chronic disease vs. one or more chronic diseases. *Frequency of use of alcohol* was grouped in eight categories from "never" to "4–7 times a week" and used as a continuous variable and dichotomized into drinking 4–7 times a week vs. less frequently. The participants were also asked about drug use. We included a variable indicating *daily use of antihypertensive medications* (yes/no), and a variable indicating daily use of psychotropic medication and analgesics, defined as drugs from at least one of the four categories: *antidepressants*, *tranquillizers*, *sedatives/hypnotics*, *and analgesics* (yes/no). The participants were also asked whether they *ever had sustained a fracture in the wrist/forearm or in the hip*. We combined the answers to these two questions into the variable "previous fracture" (yes/no).

Social participation was measured by the three questions: Do you, because of health, have permanent impairment with respect to (1) participating in organizational and other leisure time activities, (2) using public transportation, and (3) performing essential daily errands? Three response alternatives were given: no problems, some problems, or large

problems. These questions were selected according to the International Classification of Functioning (ICF) [16] in the domains of activity and participation. We defined *low societal participation* (yes/no) as having some or large problems with one or more of the three types of activity.

The participants also responded to questions about their ability to go for a 5-min walk in fairly high speed, read usual text in newspapers (with/without glasses), and hear what is being said in a normal conversation. The answering categories were as follows: with no problems, with some problems, with big problems, or unable to perform the task. We defined *low functional ability* as either having big problems or being unable to perform at least one of these three tasks.

In addition, we used the variable *study region* as a covariate—i.e., the county where the regional study had been conducted (5 categories).

Age, gender, marital status, date of death, date of emigration, and country of birth were obtained from Statistics Norway.

Hip fracture outcome

Incident hip fractures were identified by linkage to Norwegian Epidemiologic Osteoporosis Studies' national database on hip fracture: NORHip [17]. All hip fractures treated in Norwegian hospitals with a diagnosis code for cervical, trochanteric, or sub-trochanteric hip fracture (ICD 10: S72.0-S72.2) from date of examination through 31 December 2013 were available, when the cohort had reached a mean age of 86 years. The NORHip data have been obtained from all Norwegian hospitals (until 2008) and from the Norwegian Patient Registry (2008 onwards). Incident hip fractures were identified by a comprehensive algorithm taking into account surgical procedure codes, additional diagnosis codes, and time between hospitalizations. Dates of admission and discharge were available for all hospitalizations. Based on this information, admissions for primary hip fractures were identified. Information on hip fracture definitions, classification, quality assurance, and validation is available online: www.norepos.no/documentation.

Of all incident hip fractures registered during follow-up in those included in this paper, only 0.3% were sustained by participants born in non-Western countries. Analyses excluding these individuals did not change the results. Thus, country of birth was not included as a variable in the tables.

Statistical analyses

Data were analyzed in SPSS Statistics (IBM SPSS Statistics for Windows, version 27.0. Armonk, NY) and STATA, version 17.0. Each person was followed from date of participation in the study to the date of first event (hip fracture) or censored on the date of emigration, death, or end of follow-up 31 December 2013, whichever came first. Baseline data were described according to history of falling and tested for homogeneity (Pearson's 2-sided chi-squared test for categorical variables and F-test (ANOVA) for continuous variables). A *P*-value below 0.05 (2-sided test) was considered statistically significant. All analyses were performed in men and women, separately.

Log minus log curves suggested proportional hazards for falls—also with adjustments for covariates.

The bivariate associations between hip fractures and all covariates were examined in Cox proportional hazards regression. In the further analyses, we decided to use the seven dichotomous variables that showed statistically significant associations ($p < 0.05$) with both self-reported falls and risk of hip fracture after adjustments for age, BMI, smoking, and study region. These included the following: use of psychotropic medication and analgesics, social participation, self-perceived health, marital status, daily smoking, functional ability, and previous fractures. Combining each of these variables with self-reported falls, seven variables with four categories were constructed to indicate a combination of self-reported falls and the particular variable.

Furthermore, based on the three characteristics that showed the strongest association with hip fracture in women when combined with history of falling, namely daily use of psychotropic medications and analgesics, low societal participation, and poor self-perceived health, we constructed a joint variable indicating the presence or absence of each of these risk factors and history of falling.

The combined variable had the following values: (1) *none* of the three risk factors and *no* history of falling last year (reference group), (2) *none* of the three risk factors, *but* one or more falls last year, and (3) reporting all the three risk factors *and* one or more falls last year. The residual group consisted of all other combinations of the three variables and falls.

Two Cox regression models were fitted to estimate hazard ratios (HR) with 95 percent confidence intervals (95% CI) for hip fracture. Model 1 was adjusted for age, and model 2 included additional adjustment for BMI, smoking, and study region.

We also performed a Cox analysis with additional adjustments for marital status, height, education, leisure time physical activity, use of alcohol, and previous fracture (wrist/forearm and/or hip). Because there were missing answers on several of these variables (proportion of missing ranging from 0% for height to 8% for use of alcohol), complete case analyses were performed for these covariates.

Finally, we ran age-adjusted Fine and Gray competing risk analyses using the stcrreg command in STATA to estimate the risk of hip fracture taking into account the competing risk of deaths of all causes. In these analyses, cumulative incidence of hip fracture was estimated according to history

of falling combined with daily use of psychotropics/analgesics, low societal participation, and reduced self-perceived health, respectively.

Ethical approvals

Informed consent was obtained from all individual participants included in the study. Both the study and the linkages between the data sources were approved by the Regional Committee for Medical and Health Research Ethics (REK South-East A, ref 15,538), the Norwegian Institute of Public Health, the Directorate of Health, Statistics Norway, and the Norwegian Data Protection Authority. The data has been handled in accordance with the General Data Protection Regulation, and a Data Protection Impact Assessment has been conducted in consultation with the Data Protection Officer at the Norwegian Institute of Public Health. The study has been conducted in full accordance with the Declaration of Helsinki of the World Medical Association.

Results

Baseline characteristics

Among women, 1233 (32.4%) reported one or more falls during the previous year, whereas the corresponding number in men was 1786 (27.7%). Baseline characteristics of participants according to history of falling are shown in Table 1. Among women, the fallers were on average slightly older than non-fallers, while in men, fallers had higher stature than non-fallers. No differences were seen regarding BMI in either gender. Compared to non-fallers, both women and men who reported one or more falls last year had longer education and a higher level of leisure time physical activity, and a higher proportion was single. A higher percentage of the fallers than the non-fallers reported to drink alcohol 4–7 times a week, to have had a previous fracture, and to have poor/not very good self-perceived health. However, a lower proportion of fallers reported daily smoking compared to non-fallers (only statistically significant in women). A higher percentage of fallers had functional ability impairment and low societal participation. Compared to those reporting no falls last year, fallers had higher prevalence of daily use of psychotropic medication and analgesics, but no difference was found regarding use of antihypertensive medication.

Risk of hip fractures

A total of 682 women (17.9%) and 572 men (8.9%) suffered a hip fracture from baseline throughout 2013 (median follow-up 11.6 years). Compared to women with no falls last year, women with one or more falls had HR = 1.24 (95% CI 1.06–1.45) for hip fracture after adjustment for age, BMI, smoking, and study region. The corresponding risk in men was HR = 1.27 (95% CI 1.14–1.70).

Risk of hip fracture according to selected predictors combined with history of falling

Compared to non-fallers with the most beneficial characteristics (reference group), fallers who reported daily use of psychotropics/analgesics, low societal participation, or poor self-perceived health had an approximately doubled risk of hip fracture after adjustment for age, BMI, smoking, and study region (HR ranging from 1.80 to 2.55, Table 2).

When combining daily use of psychotropics/analgesics, low societal participation, and poor self-perceived health, women who reported all the three selected risk factors and at least one fall last year had HR = 2.92 (95% CI 2.10–4.05) for hip fracture after adjustments for age, BMI, smoking, and study region compared to women with none of the selected risk factors and no fall last year (reference group) (Table 3). The corresponding HR in men was 4.60 (95% CI 2.71–7.81).

Additional adjustments for marital status, height, education, leisure time physical activity, use of alcohol, and previous forearm or hip fracture in complete case analyses weakened the associations somewhat, but the increased risk in those with falls last year and presence of all three risk factors was still highly statistically significant in both genders compared to the reference group (results not shown in tables).

In an additional analysis with all-cause deaths as a competing endpoint, the age-adjusted cumulative incidence of hip fracture at median length of follow-up (11.6 years) was 20.5% in women reporting all the three risk factors and falls last year compared to 10.5% in women with none of the three risk factors and no falls ($p < 0.001$). The corresponding figure in men was 12.5% in those reporting all the three risk factors and falls last year compared to 5.8% in those with none of the three risk factors and no falls ($p = 0.012$).

For the remaining four risk factors that were associated with both hip fracture and falls (not reported in Table 2), we also assessed the combined association of self-reported falls and these characteristics separately: marital status, daily smoking, functional ability, and previous fracture (Supplementary Table 1). Compared to those *without* falls and *with* the most beneficial characteristics (reference group), single male fallers, daily smoking male fallers, male fallers with functional ability impairment, and male fallers with previous fracture had about twofold risk of hip fracture (HR ranging from 1.76 to 2.75 after adjustment for age, BMI, smoking, and study region) (Supplementary Table 1). The corresponding HRs in women with the same adjustments were somewhat lower (range 1.42–1.69). However, in contrast to the findings in men, it was the married women with a history of

Table 1 Baseline characteristics according to self-reported falls last year in 10,240 women and men 70–79 years old in the Five Counties Study, Norway

	Women ($n = 3801$)[1,2]					Men (6439)[1,2]				
		Frequency of falls last year					Frequency of falls last year			
		None	≥ One time	Total	p-value[4]		None	≥ One time	Total	p-value[4]
Number of participants[1]	N[3]	2568	1233	3801		N[3]	4653	1786	6439	
Age (years) (sd)	3801	75.1 (1.7)	75.3 (1.5)	75.2 (1.6)	< 0.001	6439	73.9 (2.4)	74.0 (2.2)	73.9 (2.2)	0.342
Height (m) (sd)	3801	1.60 (0.06)	1.60 (0.06)	1.60 (0.06)	0.079	6439	1.74 (0.06)	1.75 (0.06)	1.75 (0.06)	< 0.001
Body mass index (kg/m^2) (sd)	3801	26.9 (4.5)	26.7 (4.7)	26.8 (4.5)	0.265	6439	26.4 (3.4)	26.3 (3.4)	26.3 (3.4)	0.359
Education (years) (sd)	3694	9.4 (3.0)	10.1 (3.2)	9.7 (3.1)	< 0.001	6248	11.3 (3.8)	11.7 (4.1)	11.4 (3.9)	< 0.001
Single (%)[5]	3801	54.3	58.8	55.8	0.009	6256	22.4	26.5	23.5	0.001
Physical activity (range 1 (no) to 8 (max)) (sd)	3624	4.3 (1.6)	4.5 (1.5)	4.3 (1.6)	0.001	6322	5.0 (1.6)	5.2 (1.7)	5.1 (1.7)	0.003
Daily smoking (%)	3801	17.4	13.9	16.3	0.008	6439	19.8	17.9	19.3	0.091
Use of alcohol, 4–7 times a week (%)	3369	3.8	7.0	4.9	< 0.001	6061	10.3	12.4	10.9	0.021
Previous hip and/or forearm fracture (%)[6]	3711	34.2	38.8	35.7	0.006	6367	16.7	21.5	18.1	< 0.001
Functional ability impairment— not able to or have large problems with										
Walking 5 min. in fairly high speed (%)	3649	10.0	14.1	11.3	< 0.000	6329	5.6	9.8	6.8	< 0.001
Reading newspapers (%)	3706	3.3	4.6	3.8	0.051	6362	1.6	2.4	1.8	0.029
Hearing normal conversation (%)	3722	4.9	6.3	5.3	0.085	6372	4.5	7.8	5.4	< 0.001
Social participation—have some or large problems with respect to										
Participating in organizational and other leisure time activities (%)	3434	18.4	27.4	21.3	< 0.001	6078	11.5	19.3	13.7	< 0.001
Using public transportation (%)	3530	15.1	24.9	18.3	< 0.001	6195	5.5	11.4	7.2	< 0.001
Performing essential daily errands (%)	3641	17.4	25.8	20.2	< 0.001	6285	5.4	12.0	7.2	< 0.001
Poor/not very good self-perceived health (%)	3738	43.2	53.4	46.5	< 0.001	6341	29.8	37.2	31.8	< 0.001
One or more chronic diseases (%)[7]	3776	31.7	36.8	33.3	0.002	6428	38.0	39.6	38.4	0.240
Current use of antihypertensives (%)	3705	36.1	36.1	36.1	0.986	6312	35.4	34.8	35.2	0.678
During the last 4 weeks—daily use of										
Antidepressants (%)	2834	5.5	8.7	6.6	0.001	5490	2.0	4.2	2.6	< 0.001
Tranquilizers (%)	2890	5.9	8.5	6.8	0.010	5535	2.5	3.7	2.8	0.010
Sedatives/hypnotics (%)	3014	10.7	14.7	12.0	0.002	5588	4.5	5.8	4.8	0.033
Analgesics (%)	3118	10.0	14.1	11.4	0.001	5679	4.5	7.0	5.2	< 0.001

[1]Number of participants with available data on hip fracture, falls, age, gender, BMI, daily smoking, and study region

[2]Means and standard deviations (sd) for continuous variables, proportions (%) for categorical variables

[3]Number of answers/measured data on the different factors

[4]Tests for differences across groups of falls (Pearson 2-sided chi-squared test for categorical variables, F-test (ANOVA) for continuous variables)

[5]Single = unmarried, divorced, separated, widowed

[6]Self-reported previous fracture in distal forearm AND/OR hip (yes, no)

[7]One or more of the diseases: myocardial infarction, angina pectoris, stroke, diabetes, asthma

Table 2 Associations between selected risk factors combined with falls and hip fracture in women and men 70–79 years old in the Five Counties Study, Norway

	Women ($n=3801$)[1]					**Men (6439)**[1]				
	N[2]	No. of hip fx[3]	% hip fx[3]	HR 95% CI[4]	HR 95% CI[5]	N[2]	No. of hip fx[3]	% hip fx[3]	HR 95% CI[4]	HR 95% CI[5]
During the last 4 weeks—daily use of psychotropics and analgesics[9]										
Not daily use AND no falls	1699		15.5	1	1	3777	303	8.0	1	1
Not daily use AND falls	795	140	17.6	1.12 (0.92–1.38)	1.13 (0.92–1.39)	1383	129	9.3	1.17 (0.95–1.44)	1.20 (0.97–1.47)
Daily use AND no falls	471	91	19.3	*1.38 (1.08–1.75)*	*1.37 (1.07–1.74)*	418	50	12.0	*1.70 (1.26–2.30)*	*1.73 (1.28–2.33)*
Daily use AND falls	289	74	25.6	*2.02 (1.56–2.61)*	*2.10 (1.57–2.63)*	218	32	14.7	*2.55 (1.77–3.67)*	*2.54 (1.76–3.67)*
Total (women $p<0.001$, men $p=0.007$)	3254	568	17.5			5796	514	8.9		
Social participation[7]										
No problems AND no falls	1870	320	17.1	1	1	3947	320	8.1	1	1
No problems AND falls	759	137	18.1	1.01 (0.83–1.23)	0.99 (0.81–1.21)	1347	122	9.1	1.11 (0.90–1.36)	1.13 (0.91–1.39)
Have problems AND no falls	608	98	16.1	1.07 (0.85–1.34)	1.13 (0.90–1.42)	609	62	10.2	*1.62 (1.23–2.13)*	*1.63 (1.24–2.14)*
Have problems AND falls	440	105	23.9	*1.74 (1.40–2.17)*	*1.90 (1.52–2.37)*	403	56	13.9	*2.51 (1.89–334)*	*2.55 (1.91–3.39)*
Total (women $p=0.005$, men $p=0.001$)	3677	660	17.9			6306	560	8.9		
Self-perceived health										
Very good/good AND no falls	1432	234	16.3	1	1	3219	267	8.3	1	1
Very good/good AND falls	567	96	16.9	0.99 (0.78–1.25)	0.96 (0.76–1.22)	1103	101	9.2	1.10 (0.88–1.38)	1.13 (0.90–1.42)
Not very good/poor AND no falls	1088	185	17.0	1.17 (0.97–1.42)	1.21 (1.00–1.47)	1366	121	8.9	*1.37 (1.11–1.70)*	*1.38 (1.11–1.72)*
Not very good/poor AND falls	651	153	23.5	*1.73 (1.41–2.12)*	*1.80 (1.47–2.21)*	653	76	11.6	*1.93 (1.49–2.49)*	*1.92 (1.49–2.48)*
Total (women $p=0.001$, men $p<0.056$)	3738	668	17.9			6341	565	8.9		

Italicized values indicate significans

[1]Number of participants with available data on hip fracture, falls, age, gender, BMI, daily smoking, and study region

[2]Number of answers/measured data on the different factors

[3]fx = hip fractures

[4]Adjusted for age

[5]Adjusted for age, BMI, smoking, and study region

[6]Problems walking for 5 min in fairly high speed OR read usual text in newspapers (with/without glasses) OR hear what is being said in a normal conversation

[7]Problems with participating in organizational and other leisure time activities OR problems using public transportation OR problems performing essential daily errands (yes, no)

[8]Self-reported previous fracture in distal forearm AND/OR hip (yes, no)

[9]During the last 4 weeks—daily use of antidepressants OR sedatives/hypnotics OR tranquilisers OR analgesics (yes, no)

Table 3 Hazard ratios (HR) with 95% confidence intervals (95% CI) for incident hip fracture in combination with history of falling, daily use of psychotropics/analgesics, low societal participation, and poor self-perceived health[1] in women and men 70–79 years old in the Five Counties Study in Norway

	Women ($n = 3801$)					**Men (6439)**				
	No. of answers	No. of hip fx	% hip fx	HR 95% CI[3]	HR 95% CI[4]	No. of answers	No. of hip fx	%hip fx	HR 95% CI [3]	HR 95% CI [4]
No falls last year AND no present risk factor (reference group)	966	153	15.8	1	1	2568	197	7.7	1	1
At least one fall last year AND no present risk factor	386	58	15.0	0.88 (0.65–1.19)	0.86 (0.63–1.16)	853	70	8.2	1.04 (0.79–1.37)	1.06 (0.81–1.39)
All other combinations[2]	2290	424	18.5	*1.28 (1.06–1.54)*	*1.32 (1.09–1.59)*	2929	290	9.9	*1.52 (1.26–1.82)*	*1.57 (1.30–1.89)*
At least one fall last year AND presence of all three risk factors	158	47	29.7	*2.72 (1.96–3.77)*	*2.92 (2.10–4.05)*	89	15	16.9	*4.75 (2.81–8.05)*	*4.60 (2.71–7.81)*
Missing	1									
Total (women $p < 0.001$, men $p = 0.001$)	3801	682	17.9			6439	572	8.9		

Italicized values indicate significans

[1]The three risk factors were selected on the basis of showing the strongest associations with hip fracture in women in Cox regression (Table 2)

[2]Presence of one, two, or three risk factors combined with no falls last year, or presence of one or two risk factors combined with falls last year

[3]Adjusted for age

[4]Adjusted for age, BMI, smoking, and study region

falls who had a significant increased fracture risk ($p < 0.05$) (Supplementary Table 1).

Discussion

We found that 32.4% of the women and 27.7% of the men aged 70–79 years had fallen once or more during the last year before inclusion in the study. Self-reported poor health, low societal participation, and use of psychotropics/analgesics among the fallers were strong predictors of a future hip fracture.

Having a combination of all these three risk factors gave a particularly high risk of a future hip fracture in fallers, with a threefold risk in women and almost fivefold risk in men compared to non-fallers without these risk factors.

Falls and fractures in this study population compared to other studies

The proportion who reported one or more falls last year is in accordance with other studies showing a 1-year probability of falling in community-dwelling elderly over 65 years of about one-third [9, 18].

In agreement with other studies, we found that a number of different factors were associated with an increased risk of falling, excessive use of alcohol, use of psychotropics/analgesics, reduced speed of walking, vision impairment, one or more chronic diseases [19, 20], or previous fracture in the hip or forearm [21, 22].

During a median follow-up of 11.6 years, 17.9% of the women and 8.9% of the men sustained a hip fracture. The risk of hip fractures among participants who attended regional health studies is consistent with the high incidence in Scandinavia including Norway [23, 24].

Prediction versus causality

In search for causes of falls and fractures, the aim is to identify individual factors with a clear mechanism that explains why someone falls or sustains a fracture. However, for preventive purposes, it may initially be relevant to establish the characteristics that are available to the health care provider and helpful for identifying high-risk individuals. Such information is important for targeting preventive initiatives, both in the health care system and in the community. This study gives us information on some of these predictors. Some characteristics that indicate increased risk may not be easily modifiable. But these individuals may be attainable to other approaches like exercise programs increasing strength and balance, safety measures in the home environment, and treatment of comorbid osteoporosis. The combination of better prediction of high-risk individuals, improved coordination of care with a comprehensive evaluation of their risk factors, and tailored interventions is key to further reduction of fractures in the future.

Self-perceived health and participation in society

This study demonstrates poor self-perceived health to be a reliable predictor of future hip fracture in fallers with a nearly doubled risk of fracture in both women and men.

We found that at a group level, fallers who also reported good health did not carry any excess risk of a future hip fracture compared to non-fallers. This suggests that inquiring for falls alone in fall prevention efforts is insufficient as a risk stratification if the aim is to target high-risk individuals.

Low participation in activities outside the home was clearly associated with both previous falls and subsequent hip fractures. It is reasonable to assume that increasing problems with moving outside the residence, participating in leisure time activities, using public transportation, and performing essential daily errands are signs of a declining health; and falling may be a threshold sign of frailty and that compensatory mechanisms are overburdened.

A reduced participation in the society may in itself not be a causal factor for a future hip fracture, but more likely a consequence of ill health, and will be correlated with self-reported health. Many older people suffer from conditions like cardiovascular diseases, chronic obstructive pulmonary disease, depression, neurological diseases, and musculoskeletal disorders, but there is a considerable variability in how much impact these conditions have on their daily functioning. Information about reduced participation and self-perceived health may therefore be useful predictors for increased fracture risk in a clinical setting. Possible causal pathways for the increased risk of hip fracture are multiple, both factors that increase risk of falling [9] and conditions that may affect bone density and bone strength [25 pp. 31–45].

Most previous studies on functional abilities focus on indoor activities of daily living (ADL) [26, 27]. We suggest that reduced participation outside the home may be an earlier sign of loss of function and decline in health status than impairment of indoor ADL.

Psychotropic and analgesic medication

Daily use of psychotropic medications (antidepressants, sedatives/hypnotics, and tranquilizers) and analgesics was associated with a substantially increased risk of a future hip fracture in non-fallers, but even more in fallers with a doubled risk of hip fracture in both women and men compared to non-fallers who did not use such medication. This is in accordance with other studies [28–30].

However, it may not only be the medication itself that causes the risk of falling or a future hip fracture. In a study from Taiwan, the risk of falling was highest in the period before starting antipsychotic drugs [31]. This may also be the case for analgesics, which on the one hand may increase dizziness, but on the other hand may ease pain and difficulty related to moving about and thereby reduce fall risk.

We studied the use of psychotropics and analgesics as an indicator of increased risk of future adverse health outcomes. Regardless of whether the increased fracture risk is caused by the underlying condition or by side effects of the drug, these medications are relevant in prediction of future fractures.

Antihypertensive medication

Around a third of our total study population of 70–79 years old reported use of antihypertensive drugs, but the risk of hip fracture did not differ according to treatment for hypertension. Therefore, we did not include antihypertensive medication in the composite predictor variable indicating drug use. Orthostatic hypotension is a well-known mechanism of falls in elderly, but the underlying causes are often more complex than use of antihypertensives alone and may also be more of a problem in those who have an uncontrolled hypertension than for those who are on antihypertensive medication [32, 33]. There are conflicting results regarding an association between use of antihypertensive medication in general and risk of falling [28]. To complicate the picture further, some antihypertensives also seem protective for hip fractures [34].

Gender and marital status

Single men are known to have a lower health status compared to married men and women of any marital status [35, 36]. This study confirms that single male fallers have much higher risk of a future hip fracture than married men. Paradoxically, even when in poor health, men seek health care to a lesser degree than women, and may also evaluate their health status as better than women do [37]. In our study, a similar proportion of women (36.8%) and men (39.6%) confirmed to have one or more chronic diseases, but more women (53.4%) than men (37.2%) perceived their health as poor. Motivation to partake in efforts to prevent falls may be founded on perceived reduced health status and thereby understanding of future risk. This could make men as a group more challenging to reach in preventive care.

In the population above 70 years, women outnumber men, and have a higher risk of fractures due to osteoporosis [23] which leads to a much higher female count of hip fractures in hospitals. Among the male fallers, however, we recognize a vulnerable group who have an increased risk of a future hip fracture; men who smoke, who use psychotropics/analgesics daily, who have low participation in society, and especially if they also have a low self-perceived health.

Competing risk

Hazard ratios from Cox regression in the main analyses are conditioned on survival, as the participants contributed observation time as long as they were alive and residing in Norway [38]. The analyses thus provide estimates of the rate ratio of fracture among those actually at risk during follow-up, based on the observation time in those with and in those without the risk factor. Since the mortality was high during follow-up in this population, we also performed competing risk analyses estimating cumulative incidences of hip fracture according to history of falls and other predictors in a competing risk situation. We found that even after taking into account the high mortality, the predicted cumulative incidence of hip fracture in fallers reporting all the three risk factors was approximately twice as high compared to that in non-fallers with none of the three risk factors.

Choice of study design and outcome variables

Most randomized controlled trials (RCTs) [8, 39] that have evaluated different types of fall prevention programs have either rate of falls or number of fallers as their primary outcome and an observation time of up to 12 months. Few RCTs have longer observation time or hip fracture as primary outcome.

The major goals of fall prevention, however, are to reduce fall-related injuries like hip fractures, admittance to hospitals or nursing homes, injury-related death, and cost related to health care. With this in mind, fall as an outcome variable in fall prevention research appears insufficient, but is what is readily attainable in studies with short-term follow-up.

A couple of recent community-based RCTs [40, 41] investigating the effect of different types of fall prevention on hip fractures, other serious injuries, and hospitalizations did not show a statistically significant fracture preventive effect. It is reasonable to deduce that if the fall rate decreases by the intervention in individuals with a high risk of fracture, the fracture rate would also be reduced in the same population. One possible explanation of the null findings is that the interventions did not target fallers with a high risk of future fracture. Other explanations may be that the observation time was too short, or the studies were underpowered to detect a reduced rate of hip fracture.

It may also be unattainable to include the more vulnerable and injury-prone elderly in RCTs.

Although not the "gold standard," cohort studies may, therefore, better represent the general population, including the old and frail subpopulation with a higher risk of a future fracture.

There is clearly a need to improve the clinical assessment and identify predictors of a future fracture among the fallers in order to target those with an increased risk of serious injuries, both in studies and in clinical practices. While previous fracture is a well-known risk factor for a future hip fracture [42], and should be included in this assessment, we did not in our study have precise information on *when* the participants had their previous forearm or hip fracture, which makes the predictive value of previous fracture weaker than in other studies [42, 43] as some of the fractures may have happened many years ago. Thus, our study aimed at exploring *additional* characteristics attainable for the clinician that contribute to the prediction of future fall-related fractures to help target the high-risk population in fall prevention programs.

Strengths and weaknesses

The high number of participants and long follow-up time are major strengths in our population-based study. The cohort design is suitable for assessing relationships between individual characteristics and future hip fractures. The combination of an extensive questionnaire and a standardized physical examination is a strength, and questions about participation in activities outside the residence are of particular interest, as this is not included in most studies.

Norway has universal health coverage with a virtually complete national registry (Norwegian Patient Registry) covering all hip fractures treated in Norwegian hospitals, providing data to the NORHip database utilized in this analysis.

Fewer men than women sustain hip fractures, and the high number of men in our study enables us to study this group in more depth.

A general weakness in population-based cohort studies is the participation rate. Even though all in the selected age group in the targeted areas were invited to participate, only a little more than half attended. A possible selection bias may be suspected with less participation among those with mental health or addiction issues, trouble moving about, or in poor general health.

However, for a subgroup of this study population, the effect of this possible self-selection has been studied. The authors concluded that self-selection according to sociodemographic variables had little impact on prevalence estimates [13]. The participation rate is also less critical when the aim of the study is to describe associations, as opposed to studying prevalence.

A questionnaire is also vulnerable to mistakes in reporting due to memory issues or underreporting of sensitive information like addiction. The long observation time will also reduce the value of reported falls and other information as time goes by and the participants' health status change from the time of inclusion.

Norway has as the other Scandinavian countries a very high incidence of hip fractures, and not only during wintertime [44, 45]. Furthermore, the country has a cradle-to-grave follow-up through universal health care and an advanced welfare system. However, it was not within our scope to explain fracture incidence or mortality, nor seasonal variability in Norway. We examined predictors for subsequent hip fractures specifically among fallers, and our main findings might be applicable to countries outside Norway as well.

Implications

Health care providers are encouraged to ask seniors about falling on a yearly basis [26]. Our findings suggest that combining self-assessment of health status and questions about activities outside the residence with knowledge about previous fractures and use of medication in the patient, represents valuable information to help target those with the highest risk of future fracture and who potentially would benefit most from a fall and fracture prevention program. This is readily available information in any consultation if asked for.

Early detection of reduced participation in society provides an opportunity for intervention at a stage where the decline in health may be easier to curb. The health care providers should be observant of single men who have fallen the previous year as a particularly vulnerable group and who may have a high threshold for seeking help when needed.

Conclusion

In conclusion, poor self-reported health, low societal participation, and daily use of psychotropic medication or analgesics are predictors of future hip fracture in fallers. These factors may support the clinician in evaluating the risk of a future hip fracture and need of preventive interventions.

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Declarations

Conflicts of interest Data from the Norwegian Patient Registry have been used in this publication. The interpretation and reporting of these data are the sole responsibility of the authors, and no endorsement by the Norwegian Directorate of Health is intended nor should be inferred.

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