Fall Risk Assessment Predicts Fall-Related Injury, Hip Fracture, and Head Injury in Older Adults

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Fall Risk Assessment Predicts Fall-Related Injury, Hip Fracture, and Head Injury in Older Adults

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OBJECTIVES: To investigate the role of a fall risk assessment, using the Downton Fall Risk Index (DFRI), in predicting fall-related injury, fall-related head injury and hip fracture, and death, in a large cohort of older women and men residing in Sweden.

DESIGN: Cross sectional observational study.

SETTING: Sweden.

PARTICIPANTS: Older adults (mean age 82.4 ± 7.8) who had a fall risk assessment using the DFRI at baseline (N = 128,596).

MEASUREMENTS: Information on all fall-related injuries, all fall-related head injuries and hip fractures, and all-cause mortality was collected from the Swedish Patient Register and Cause of Death Register. The predictive role of DFRI was calculated using Poisson regression models with age, sex, height, weight, and comorbidities as covariates, taking time to outcome or end of study into account.

RESULTS: During a median follow-up of 253 days (interquartile range 90–402 days) (>80,000 patient-years), 15,299 participants had a fall-related injury, 2,864 a head injury, and 2,557 a hip fracture, and 23,307 died. High fall risk (DFRI ≥3) independently predicted fall-related injury (hazard ratio (HR) = 1.43, 95% confidence interval (CI) = 1.39–1.49), hip fracture (HR = 1.51, 95% CI = 1.38–1.66), head injury (HR = 1.12, 95% CI = 1.03–1.22), and all-cause mortality (HR = 1.39, 95% CI = 1.35–1.43). DFRI more strongly predicted head injury (HR = 1.29, 95% CI = 1.21–1.36 vs HR = 1.08, 95% CI = 1.04–1.11) and hip fracture (HR = 1.41, 95% CI = 1.30–1.53 vs HR = 1.08, 95% CI = 1.05–1.11) in 70-year old men than in 90-year old women ($P < .001$).

CONCLUSION: Fall risk assessment using DFRI independently predicts fall-related injury, fall-related head injury and hip fracture, and all-cause mortality in older men and women, indicating its clinical usefulness to identify individuals who would benefit from interventions. **J Am Geriatr Soc 64:2242–2250, 2016.**

Key words: fall risk assessment; fall-related head injury; hip fracture; men; women

Approximately one-third of all people aged 65 and older fall at least once yearly,[1,2] and this proportion increases with age and declining health.[3,4] Accidental falls are associated with morbidity, mortality, and nursing home placement.[5] Half of falls result in an injury, but only 10% of falls in people aged 65 and older lead to serious injury such as hip fracture, other fracture, or head injury.[2,6] Falls are the leading cause of traumatic brain injury (TBI) in older adults, and mortality is much greater in older adults with TBI than in their younger counterparts.[7] Hip fractures lead to greater risk of death and disability and substantial healthcare costs.[8–10] Although accidental falls in elderly adults have been the subject of extensive research in recent decades, they are a growing major health concern, with substantial medical and economic consequences in a rapidly aging global population.[11,12] According to a recent report, disability due to falls increased by 54% between 1990 and 2010, accounted for 864,000 years lived with disability, and ranked as the 11th most common cause of disability in 2010.[13] The cost of fall-related injuries was recently reported to be 0.85% to 1.5% of total national healthcare expenditures.[13]

Accurate assessment using fall risk screening is a widely recommended strategy to identify older persons who will benefit from an intervention to prevent accidental falls.[2,11] The Downton Fall Risk Index (DFRI) is a composite risk index that takes into account several factors known to increase fall risk, such as antihypertensive medications, sedatives, previous falls, cognitive disability, and

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impaired motor skills.[14] Antihypertensive medications increased serious injuries due to falls in a large cohort of community-living adults in the United States.[15] Several fall risk indexes, including the DFRI, which has the highest sensitivity, can predict falls in older adults,[16] but it is unknown whether these instruments predict clinically relevant outcomes, such as serious injury and death.

The aim of the study was to investigate the role of a fall risk assessment, using the DFRI, in predicting fall-related injury, head injury, hip fracture, and death, in a large cohort of older women and men residing in Sweden who are in contact with caregivers.

METHODS

Participants and Study Design

The included cohort was identified using well-characterized national directories in which data on fall risk screening, fractures, other fall-related injuries, morbidity, medication, and mortality are available. From January 1, 2008, through December 31, 2011, 128,596 men and women aged 82.4 ± 7.8 were included from the Swedish directory Senior Alert (Figure 1), a national directory in which licensed allied health professionals (assistant and registered nurses, registered physical therapists or registered occupational therapists) screen Swedish citizens aged 65 and older who are in contact with specific parts of the healthcare system for fall risk, regardless of diagnosis, functioning, disability, or health. Hospitals, residential care facilities, primary health care, and home health care that provide care with skilled professionals are included. The register was instituted with the aim of increasing the proportion of individuals with high risk of falls, pressure ulcers, and undernutrition that receive interventions to reduce their risk.[17] At the time of data extraction, 18 of 21 (90.5%) healthcare regions were represented in Senior Alert, and 261 of 290 (90%) municipalities in Sweden registered individuals in Senior Alert. Risk of falling, assessed using the Downton Fall Risk Index (DFRI)[14] at admission, age, height, and weight were registered in Senior Alert. Height was available for 128,448 individuals and weight for 127,838. DFRI consists of a composite index of established fall risk factors classified into five nominal groups: known previous falls, medications (tranquilizers, sedatives, diuretics, antihypertensives, antiparkinsonian drugs, antidepressants), sensory disability (visual or hearing impairment, impaired motor skills (reduced muscle strength or loss of function in a limb)), cognitive disability (orientation to time, place, and person), and walking ability (unsafe gait)). Scores for each risk factor are added to produce an index sum (range 0 –11; DFRI score). A score of three or greater is taken to indicate a high risk of fall[18,19] and warrants an intervention including fall-

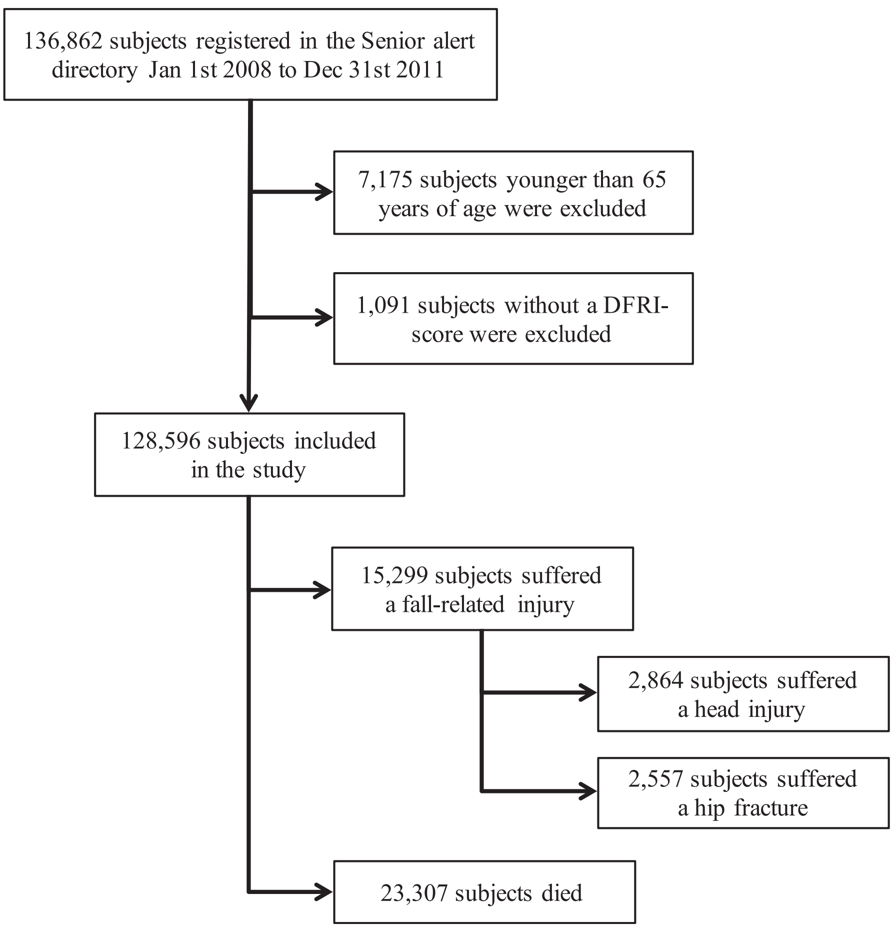

Figure 1. Flow diagram depicting inclusion and exclusion of subjects in the study.

preventive actions to enter into the register. Risk factors and total DFRI scores were obtained from the admission assessment data and used as predictive indicators of the risk of serious clinical outcomes requiring a visit to the hospital or hospital admission. Of the 77,957 participants with high fall risk (DFRI ≥3), only 43,291 (55.5%) had one or more interventions registered in the Senior Alert. Therefore, register data regarding interventions were deemed unreliable and were not used. Information on the identified cohort regarding prevalent and incident fractures and other fall-related injuries, current diseases (anemia, diabetes mellitus types 1 and 2, Alzheimer's disease, cataracts, hypertension, congestive heart failure, chronic ischemic heart disease, atrial fibrillation, stroke, chronic obstructive pulmonary disease, asthma, arthrosis of the hip or knee, chronic kidney disease) (the Patient Register), and death (the Cause of Death Register) was collected through coordination with national registers administered by the National Board of Health and Welfare, covering data from January 1, 2008, through December 31, 2011. The Patient Register contains all diagnoses and procedures recorded at hospitals in Sweden. Information about immigration and emigration (the Total Population Register) was collected through coordination with national directories administered by Statistics Sweden, covering data from January 1, 2008, through December 31, 2011. Time in study was calculated from date of study entry to time of death, other outcome, or emigration. Fall-related injury was classified using the *International Classification of Diseases, Tenth Revision* (ICD-10) in participants with codes for both a fall (W00-W19) and injury (S00-T14). Any head injury (superficial injury of head (S00); open wound of head (S01); fracture of skull and facial bones (S02); dislocation, sprain, and strain of joints and ligaments of head (S03); injury of cranial nerves (S04); injury of eye and orbit (S05); intracranial injury (S06); crushing injury of head (S07); traumatic amputation of part of head (S08); and other and unspecified injuries of head (S09)) or hip fracture (S72.0–1) and cause of death were identified using ICD-10 codes in the Patient Register (Table S1). ICD-10 codes for hip and femur fractures were used only if there was a corresponding code according to the classification of surgical procedures[20] (NF, surgical procedures on the femur) from the same occasion.

Data on prevalent osteoporotic fracture between January 1, 2008, and the risk estimate date were retrieved from the Patient Register. The regional ethical review board in Gothenburg approved the study.

Statistical Analyses

Independent-samples *t*-tests were used for between-group comparisons (Table 1). Spearman bivariate correlations were used to test the relationship between DFRI score, anthropometric traits, prevalent fracture, and incidence of the outcomes fall-related injury, head injury, hip fracture, and death (Table 2). Participants with DFRI scores from 7 to 11 were combined because of power problems with too few subjects with DFRI scores greater than 6. Cox proportional hazards models adjusted for age, height, weight, sex, and comorbidity were used to investigate the association between DFRI score and fall-related injuries and mortality (Table 3). Cox proportional hazards models were also used when studying the predictive role of age for the risk of fall-related outcomes. An extension of a Poisson regression model[21] was used to study the association between age, time since baseline, sex, weight, height, DFRI score, and risk of an outcome (Figure 2). A piecewise linear model with knots at DFRI scores 1, 2, 3, 4, 5, and 6 was used to be able to study an assumed nonlinear relationship between DFRI score and risk of an outcome. The observation period for each participant was divided into 1-month intervals. One outcome per person and time to the first outcome of interest were counted. Associations between predictive factors and risk of outcome were described as a hazard ratio (HR) per 1-unit deviation change. Poisson regression was also used when studying the interaction between DFRI score and age as a covariate, in addition to sex, weight, height, and time in study.

RESULTS

Participant Characteristics

The baseline characteristics and DFRI components of the 128,596 participants are presented in Table 1 according to the main outcome measures fall-related injury, fall-related head injury and hip fracture, and all-cause mortality. Participants were primarily identified at hospitals (54.8%), in residential care facilities (35.5%), in primary health care (4.4%), and in home health care (4.9%). Mean age at inclusion was 82.4 ± 7.8, and the majority of participants were women (59.6%). At baseline, 40.9% had a history of falls, and large proportions of the cohort had other risk factors for falling, including antihypertensive medication (40.6%), impaired eyesight (43.7%), cognitive disability (27.7%), and unsafe gait (30.8%) (Table 1). During a median follow-up of 253 days (interquartile range (IQR) 90–402 days), 15,299 (11.9%) participants had a fall-related injury, 2,864 (2.2%) a head injury, and 2,557 (2.0%) a hip fracture, and 23,307 (18.1%) died. Greater DFRI score was associated with older age; female sex; incident fall-related injury, head injury, and hip fracture; greater all-cause mortality; shorter height; and lower weight (Table 2). The most common (≥0.1% of the study cohort) fall-related injuries are presented in Table S2. Using a normal distribution plot (Figure S1), it was found that the distribution of DFRI could be well approximated using a normal distribution with a standard deviation of 2.0.

DFRI Predicts Fall-Related Injury

Each step in the DFRI scale was associated with a 10% greater risk in fall-related injury (HR = 1.10, 95% CI = 1.09–1.11), which corresponded to the greater risk seen with a 10-year difference in age (HR = 1.01, 95% CI = 1.01–1.01 per year). Using a nonlinear analysis, participants with a DFRI score of three or greater had a greater risk of fall-related injury. Participants with a DFRI score of six or greater had a risk of fall-related injury of more than 20 per 100 person-years (Figure 2A). Also after adjusting for multiple comorbidities, DFRI scores of three or greater (HR = 1.43, 95% CI = 1.39–1.49) and seven or

Table 1. Characteristics of the Total Cohort and According to Main Outcomes

Characteristic	All, N = 128,596	Fall-Related Injury Yes, n = 15,299	Fall-Related Injury No, n = 113,297	Hip Fracture Yes, n = 2,557	Hip Fracture No, n = 126,039	Head Injury Yes, n = 2,864	Head Injury No, n = 125,732	All Cause Mortality Yes, n = 23,307	All Cause Mortality No, n = 105,289
Age, mean ± SD	82.4 ± 7.8	83.4 ± 7.4	82.2 ± 7.8[c]	85.0 ± 6.8	82.3 ± 7.8[c]	83.3 ± 7.5	82.4 ± 7.8[c]	84.6 ± 7.5	81.9 ± 7.6[c]
Height, cm, mean ± SD (N = 128,448)	165.7 ± 9.8	164.6 ± 9.6	166.0 ± 9.8[c]	164.1 ± 9.6	165.9 ± 9.8[c]	165.5 ± 9.9	165.9 ± 9.8[a]	166.0 ± 10.0	165.8 ± 9.7[a]
Weight, kg, mean ± SD (N = 127,838)	70.2 ± 16.2	67.5 ± 15.6	70.6 ± 16.2[c]	64.4 ± 14.2	70.3 ± 16.2[c]	67.5 ± 15.2	70.3 ± 16.2[c]	66.5 ± 15.8	71.0 ± 16.1[c]
Female, %	59.6	67.6	58.5[c]	67.0	59.4[c]	57.5	59.6[a]	55.1	60.5[c]
Person-years		80,265		88,761		80,468		90,127	
Downton Fall Risk Index score, median (interquartile range)	3.0 (2)	3.0 (3)	3.0 (2)	4.0 (3)	3.0 (2)	3.0 (3)	3.0 (2)	4.0 (3)	3.0 (2)
Previous fall, %	40.9	56.6	38.8[c]	54.9	40.6[c]	58.7	40.5[c]	45.4	39.9[c]
Current medication, %									
Neuroleptic	30.8	33.1	30.5[c]	38.6	30.6[c]	34.9	30.7[c]	35.6	29.7[c]
Diuretics	33.8	33.8	33.7	34.4	33.7	34.4	33.7	42.9	31.7[c]
Other antihypertensive	40.6	40.9	40.6	39.7	40.6	42.4	40.6	38.8	41.0[c]
Antiparkinson	3.3	3.9	3.2[c]	4.4	3.2[c]	4.6	3.2[c]	3.6	3.2[b]
Antidepressant	19.9	21.6	19.6[c]	25.0	19.8[c]	23.4	19.8[c]	20.9	19.6[c]
Sensory disability, %									
Visual impairment	43.7	48.1	43.1[c]	46.3	43.7[b]	46.8	43.7[b]	45.2	43.4[c]
Hearing impairment	28.0	30.7	27.7[c]	33.6	27.9[c]	31.5	28.0[c]	33.4	26.9[c]
Impaired motor skills	11.6	8.2	12.1[c]	8.3	11.7[c]	9.1	11.7[c]	15.0	10.9[c]
Cognitive disability	27.7	27.9	27.6	39.0	27.4[c]	30.9	27.6[c]	38.3	25.3[c]
Walking ability, unsafe gait	30.8	40.9	29.5[c]	41.8	30.6[c]	41.4	30.6[c]	38.4	29.2[c]

Differences between groups (yes, no) tested using independent samples *t*-test for continuous variables, [a]$p < .05$, [b]$p < .01$, [c]$p < .001$.
SD = standard deviation.

Table 2. Characteristics of the Cohort According to Downton Fall Risk Index (DFRI) Score

Characteristic	DFRI Score								P-Value
	0, n = 11,525	1, n = 15,027	2, n = 24,087	3, n = 25,346	4, n = 22,556	5, n = 16,184	6, n = 8,996	7–11, n = 4,875	
Age	79.5 ± 8.0	79.0 ± 7.5	80.9 ± 7.6	82.6 ± 7.6	83.9 ± 7.4	84.7 ± 7.3	85.3 ± 7.0	85.9 ± 6.8	<.001
Height, cm, mean ± SD (N = 128,448)	167.9 ± 9.7	167.8 ± 9.6	166.5 ± 9.7	165.6 ± 9.8	165.0 ± 9.7	164.7 ± 9.8	164.2 ± 9.7	164.2 ± 9.7	<.001
Weight, kg, mean ± SD (N = 127,838)	71.9 ± 16.0	72.6 ± 15.7	71.5 ± 16.1	70.0 ± 16.5	69.1 ± 16.2	68.6 ± 16.0	68.1 ± 15.8	68.4 ± 15.9	<.001
Female, %	53.6	52.4	56.8	60.2	62.9	64.1	65.1	65.3	<.001
Prevalent osteoporotic fracture, n (%)	1,441 (12.5)	1,303 (8.7)	2,728 (11.3)	3,967 (15.7)	4,402 (19.5)	3,690 (22.8)	2,246 (25.0)	1,351 (27.7)	<.001
Incident fall-related injury, n (%)	1,013 (8.8)	1,247 (8.3)	2,458 (10.2)	3,158 (12.5)	3,030 (13.4)	2,231 (13.8)	1,389 (15.4)	773 (15.9)	<.001
Incident head injury, n (%)	1.6 (176)	1.5 (222)	1.7 (409)	2.5 (609)	2.5 (556)	2.7 (426)	3.4 (294)	3.7 (172)	<.001
Incident hip fracture, n (%)	132 (1.1)	164 (1.1)	402 (1.7)	491 (1.9)	526 (2.3)	434 (2.7)	254 (2.8)	154 (3.2)	<.001
All cause mortality, n (%)	1,436 (12.5)	1,726 (11.5)	3,534 (14.7)	4,723 (18.6)	4,577 (20.3)	3,648 (22.5)	2,281 (25.4)	1,382 (28.3)	<.001

P-values are for nonparametric bivariate correlation (Spearman rho) between DFRI score (0–11) and the different variables.

Table 3. High Fall Risk as a Predictor of Fall-Related Injury, Hip Fracture, and Head Injury, Adjusted for Comorbidity

Outcome	DFRI ≥3 vs 1–2 HR = (95% Confidence Interval)	DFRI ≥7 vs 1–2
Fall-related injury	1.43 (1.39–1.49)	1.36 (1.26–1.46)
Hip fracture	1.51 (1.38–1.66)	1.51 (1.29–1.79)
Head injury	1.12 (1.03–1.22)	1.32 (1.13–1.55)
Mortality	1.39 (1.35–1.43)	1.44 (1.37–1.53)

A Cox proportional hazards model with height and weight as covariates was used to investigate the predictive role of a Downton Fall Risk Index (DFRI) score of three or greater and seven or greater, adjusted for age, sex, height, weight, anemia, diabetes mellitus type 1 and 2, Alzheimer's disease, cataracts, hypertension, congestive heart failure, chronic ischemic heart disease, atrial fibrillation, stroke, chronic obstructive pulmonary disease, asthma, arthrosis of the hip or knee, and chronic kidney disease vs a DFRI score of 1 to 2.

greater (HR = 1.36, 95% CI = 1.26–1.46) were associated with greater risk of fall-related injury than a DFRI score less than 3 (Table 3). The five most common fall-related injuries were to the hip and thigh (n = 4,409, 28.8%); the head (n = 2,864, 18.7%); the shoulder and upper arm (n = 2,199, 14.4%); the abdomen, lower back, lumbar spine, and pelvis (n = 1,901, 12.4%); and the elbow and forearm (n = 1,707, 11.2%) (Table S3).

DFRI Predicts Hip Fracture

Every step in the DFRI scale was associated with a 14% greater risk of hip fracture (HR = 1.14, 95% CI = 1.12–1.17), which was equal to the increase in risk seen with a 4-year difference in age (HR = 1.04, 95% CI = 1.03–1.04 per year). In the nonlinear analysis, the risk of hip fracture increased in parallel with DFRI score in participants with a DFRI score of one or greater (Figure 2B). DFRI predicted hip fracture also after adjusting for multiple comorbidities. A DFRI score of three or greater was associated with 51% greater risk of hip fracture (HR = 1.51, 95% CI = 1.38–1.66) than a DFRI score less than 3 (Table 3).

DFRI Predicts Head Injury

One thousand ninety-three (38.2%) participants had an intracranial injury (Table S3). DFRI predicted greater risk of a fall-related head injury (HR = 1.16, 95% CI = 1.14–1.18) and fall-related intracranial injury (HR = 1.16, 95% CI = 1.12–1.20). Using a nonlinear analysis, the risk of fall-related head injury was nearly two per 100 person-years for participants with DFRI of two or less and appeared to increase with a DFRI of three or greater, and with a DFRI of seven or greater, the risk rose to five or more per 100 person-years (Figure 2C). The predictive role of one step in DFRI corresponded to a 16.9-year increase in age (HR = 1.01, 95% CI = 1.00–1.01). DFRI predicted head injury after adjusting for multiple comorbidities. A DFRI score of three or greater was associated with 12% greater risk of head injury (HR = 1.12, 95% CI = 1.03–1.22) than a DFRI score less than 3 (Table 3), and a DFRI

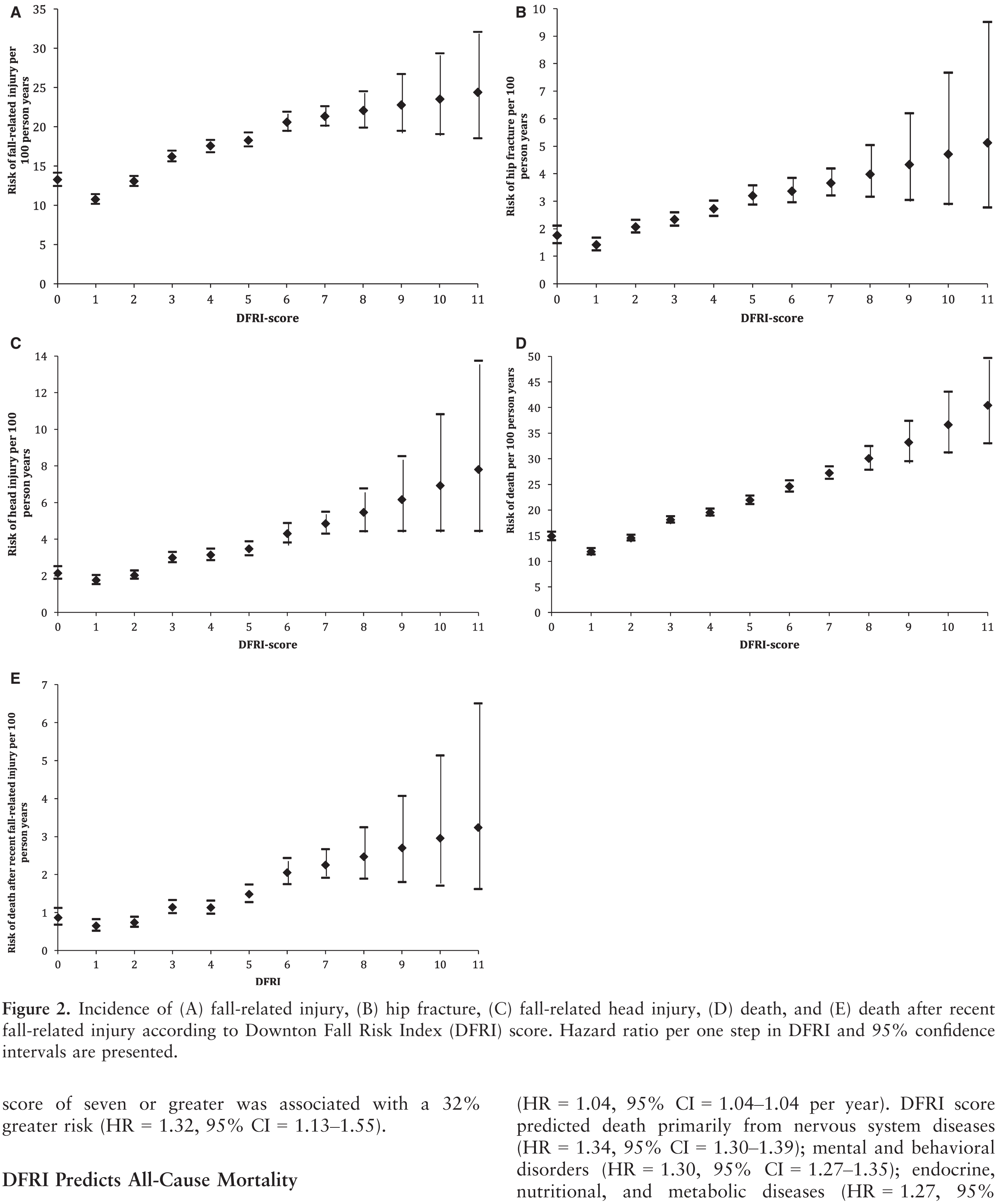

Figure 2. Incidence of (A) fall-related injury, (B) hip fracture, (C) fall-related head injury, (D) death, and (E) death after recent fall-related injury according to Downton Fall Risk Index (DFRI) score. Hazard ratio per one step in DFRI and 95% confidence intervals are presented.

score of seven or greater was associated with a 32% greater risk (HR = 1.32, 95% CI = 1.13–1.55).

DFRI Predicts All-Cause Mortality

The most common causes of mortality in the cohort were cardiovascular disease (42.2% of the deceased), neoplasms (22.6%), mental and behavioral disorders (7.4%), and respiratory diseases (6.6%) (Table S1). Each step in the DFRI scale was associated with 12% greater all-cause mortality (HR = 1.12, 95% CI = 1.11–1.13), which was similar to the risk increase seen with a 3-year difference in age (HR = 1.04, 95% CI = 1.04–1.04 per year). DFRI score predicted death primarily from nervous system diseases (HR = 1.34, 95% CI = 1.30–1.39); mental and behavioral disorders (HR = 1.30, 95% CI = 1.27–1.35); endocrine, nutritional, and metabolic diseases (HR = 1.27, 95% CI = 1.21–1.33); and external causes of morbidity and mortality (HR = 1.22, 95% CI = 1.17–1.28) (Table S2). In a nonlinear analysis, survival was greatest in participants with a DFRI score of 1. All-cause mortality increased in a linear fashion in participants with higher DFRI scores (Figure 2D). One thousand four hundred forty-three participants died within 3 months after a fall-related injury. DFRI score independently predicted (in a model adjusted as described above) occurrence of death after a recent fall-related injury (HR = 1.21, 95% CI = 1.17–1.24) (Figure 2E). Four hundred fifty-eight participants died within 3 months after a head injury. DFRI score also independently predicted death after a recent fall-related injury (HR = 1.16, 95% CI = 1.10–1.23). Participants with DFRI scores of three or greater had a 39% greater risk of dying than those with a DFRI score less than three and those with a score of seven or greater had a 44% greater risk, after adjusting for multiple morbidities (Table 3).

DFRI Interaction With Age and Sex

Significant interactions were seen between age and DFRI score in men in the analyses with fall-related injury (aged 70: HR = 1.23, 95% CI = 1.20–1.27 vs 90 HR = 1.12, 95% CI = 1.09–1.14), hip fracture (HR = 1.41, 95% CI = 1.30–1.53 vs HR = 1.12, 95% CI = 1.06–1.17), and head injury (HR = 1.29, 95% CI = 1.21–1.36 vs HR = 1.15, 95% CI = 1.10–1.20) as outcome measures ($P < .001$). DFRI score more strongly predicted all of these outcomes in younger than in older adults. Similar interactions were also found in women (data not shown). Significant interactions were also seen between sex and DFRI score in the analyses with fall-related injury (men: HR = 1.16, 95% CI = 1.15–1.18 vs women: HR = 1.07, 95% CI = 1.06–1.08), hip fracture (HR = 1.20, 95% CI = 1.16–1.25 vs HR = 1.11, 95% CI = 1.08–1.14), and head injury (HR = 1.20, 95% CI = 1.17–1.24 vs HR = 1.12, 95% CI = 1.09–1.15) as outcome measures ($P < .001$). DFRI score more strongly predicted fall-related injury (HR = 1.23, 95% CI = 1.20–1.27 vs HR = 1.05, 95% CI = 1.04–1.07), head injury (HR = 1.29, 95% CI = 1.21–1.36 vs HR = 1.08, 95% CI = 1.04–1.11), and hip fracture (HR = 1.41, 95% CI = 1.30–1.53 vs HR = 1.08, 95% CI = 1.05 to1.11) in 70-year old men than in 90-year old women ($P < .001$).

DISCUSSION

Fall risk prediction instruments are useful in predicting falls, but it is unclear whether these instruments can predict severe clinical outcomes resulting from falls. In this large Swedish cross-sectional observational study, in many cases, fall risk assessment using the DFRI predicted severe clinical outcomes such as fall-related injury, head injury, hip fracture, and death. Thus, fall risk evaluation provides important information needed to determine the risk of severe clinical outcomes. These data underscore the importance of performing fall risk assessment to identify individuals at high risk so that preventive measures can be taken. Exercise programs, multifactorial interventions, home safety interventions, and antislip shoe devices can reduce the rate of falls.[12] Mainly because previous studies were underpowered, the evidence for these interventions to reduce fall-related injuries has been insufficient. A recent meta-analysis of 17 trials reported that fall prevention exercise programs prevented injuries caused by falls in older community-dwelling people.[22] The authors report risk reductions reaching 37% for injurious falls, 61% for falls resulting in fractures, and 43% for severe injurious falls as a result of exercise interventions.[22]

In the current study, nearly 12% of the included individuals had a fall-related injury resulting in a hospital visit during the short median follow-up time (253 days). This proportion varied from 9% in participants with a low DFRI score to 16% in participants with higher DFRI scores. DFRI score predicted fall-related injury independently of age, sex, and anthropometric characteristics, with a risk increase per step in DFRI scale of approximately 4 years of age. More importantly, DFRI predicted severe injuries such as head injury and hip fracture. Fall risk increases with aging in both sexes.[3] The current analyses demonstrate that the independent contribution of DFRI in predicting fall-related injury was considerably greater for a 70- than a 90-year-old individual. This interaction was also seen for head injury and hip fracture. The predictive ability of DFRI was also significantly greater in men than in women for major outcomes such as hip fracture and head injury. Thus, the predictive value of DFRI was considerably stronger in younger men than in older women. Information about frailty and known morbidity may be more important in the prediction of fall-related injuries in older adults. Furthermore, these results indicate that a DFRI score of seven or greater had no obvious advantage in estimating risk of falling over a DFRI score of three or greater.

Guidelines in the United Kingdom and United States recommend that general practitioner or other health professionals ask older adults (or their caregivers) about falls within the past year and screen for deficits in gait and balance at least once yearly.[23] Individuals with a recent fall and unsteadiness should then be more thoroughly evaluated for fall risk, taking other risk factors such as fall-inducing medication, reduced visual acuity, and muscle strength into account as well. Although some falls have a single cause, the majority result from interactions between multiple risk factors.[5,24,25] Furthermore, the risk of falling consistently increases as the number of risk factors increases,[2,26] emphasizing the importance of evaluating a multitude of known risk factors. Such a multifactorial risk factor evaluation can be performed using the standardized DFRI,[14] which also an allied health professional could also used, not requiring a consultation by, for example, a general practitioner. Evidence from several metaanalyses of randomized trials of fall prevention suggests that exercise and multifactorial interventions to prevent falls are effective.[12] Using the DFRI to select individuals who should undergo interventions to reduce fall injury risk could save considerable healthcare resources. Head injury is one of the most-severe outcomes from a fall. Falls are the leading cause (51%), followed by motor vehicle accidents (9%), of TBI in older adults. Mortality is much greater in older adults with TBI than in their younger counterparts.[7] The ability of the DFRI to predict head injury as a possible cause of death, as found in the current study, emphasizes the importance of fall risk evaluation to identify high-risk individuals. Bone fragility and falls are important risk factors for osteoporotic fracture,[27] but fall risk has not yet been included in the World Health Organization fracture risk calculation tool (FRAX).[28] The estimated worldwide incidence of fragility fractures in men and women aged 50 and older in 2000 was 9 million, of which fall-related fractures of the hip accounted for 1.6 million.[29] Adding a fall risk assessment to FRAX could be of great value, although further studies including all FRAX variables are needed to evaluate the role of DFRI.

Some limitations with this study should be acknowledged. Even though all individuals from the register with an initial fall risk assessment were included, the representativeness of the register can be questioned. At the time of data extraction, approximately 90% of municipalities registered individuals in Senior Alert, but the registration rate at each healthcare facility could not be determined. In addition, a majority of the included individuals were identified at hospitals (54.8%) or in residential care facilities (35.5%). Therefore, the predictive role of DFRI for clinical outcomes may not be fully representative and apply to all older populations seeking health care. Because participants who died during the study had a higher DFRI score than those who were still alive, the possibility cannot be excluded that DFRI score is a surrogate for frailty. More studies are needed to investigate this. In addition, fall-related injuries that did not require a hospital visit were not detected in this study. Thus, no information was available on the number of individuals who fell. Although all fall-related injuries were classified using the ICD-10 with codes for both a fall and injury, some injuries may have been misclassified as not being fall related. Furthermore, it was not possible to investigate the role of any applied interventions because of a low rate of recorded interventions in the register.

Even though the DFRI can predict falls in older adults with high sensitivity,[16] a previous comparison between DFRI and nurses' judgment alone, accompanied by a fall preventive intervention, showed no benefit regarding clinical outcome of the DFRI in nursing homes.[30] That said, in nursing homes, the nurses are generally familiar with residents' health status, including all components of the DFRI. In contrast, at admission to a hospital, nurses are most often meeting the individual for the first time, without any prior knowledge of the DFRI components. Hence, the use of the DFRI may be less relevant in nursing homes than in hospitals. The strengths of this study include the large sample size and the outcomes investigated, which are highly clinically relevant.

In conclusion, these data provide evidence that a fall risk assessment using the DFRI independently predicts fall-related injury, fall-related head injury and hip fracture, and all-cause mortality in older men and women, indicating its clinical usefulness in identifying individuals who would benefit from interventions. DFRI was found to have a better predictive ability for these outcomes in 70-year-old men than in 90-year-old women.

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The regional ethical review board in Gothenburg approved the study.

Conflict of Interest: The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this paper.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table S1. Identification of osteoporotic fractures and head injury using ICD-10 codes in the Patient Register.

Table S2. Cause of Mortality in the Senior Alert Patient Cohort.

Table S3. The Most Common Types of Injuries Caused by a Fall in the Senior Alert Patient Cohort.

Table S4. DFRI as Predictor of Mortality in the Senior Alert Patient Cohort.

Figure S1. Normal distribution plot.

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