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ORIGINAL ARTICLE

Predictors of hip fracture in 15 European countries: a longitudinal study of 48,533 geriatric adults using SHARE dataset

M. Azhar Hussain[1,2] · Rizwan Qaisar[3,4] · Asima Karim[3] · Firdos Ahmad[3,4] · Fabio Franzese[5] · Atif Awad[1] · Abeer A. Al-Masri[6] · Mohammed Alsaeed[7] · Shaea A. Alkahtani[8]

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Abstract

Summary We investigated the risk factors for hip fracture in 48,533 European older adults for 8 years from 2013 onward. We identified female gender, age above 80, low handgrip strength, and depression as significant risk factors for hip fracture. Our findings may help identify high-risk populations for hip fractures in pre-clinical settings.

Objectives Hip fracture is a major cause of functional disability, mortality, and health costs. However, the identification and characterization of its causative factors remain poor.

Methods We investigated demography, handgrip strength (HGS), depression, and multiple age-associated comorbidities for predicting future hip fracture in individuals aged 50 or above from 15 European countries ($n = 48{,}533$). All participants were evaluated from 2013 to 2020 using four successive waves of the Survey of Health, Aging, and Retirement in Europe (SHARE).

Results Altogether, 1130 participants developed hip fractures during the study period. We identified female gender, an advancing age from quinquagenarians onward, and a poor socioeconomic status as critical risk factors for future hip fracture. Having mobility difficulty, a low HGS (< 27 kg in men, < 16 kg in women) and higher scores on Euro-D depression scales were also significant risk factors for hip fracture. Summated scales of hypertension, diabetes mellitus, cancer, Alzheimer's disease, and stroke did not appear as risk factors.

Conclusion Collectively, we report advancing age, female gender, low HGS, and depression as independent risk factors for hip fracture. Our findings are useful in identifying high-risk populations for hip fractures in pre-clinical settings before rigorous evaluation and treatment in clinics.

Keywords Hip fracture · Risk factors · Handgrip strength · Euro depression scale · Multi-comorbidity

✉ Shaea A. Alkahtani
shalkahtani@ksu.edu.sa

[1] Department of Finance and Economics, College of Business Administration, University of Sharjah, Sharjah 27272, UAE

[2] Department of Social Sciences and Business, Roskilde University, 4000 Roskilde, Denmark

[3] Basic Medical Sciences, College of Medicine, University of Sharjah, 27272 Sharjah, United Arab Emirates

[4] Cardiovascular Research Group, Research Institute for Medical and Health Sciences, University of Sharjah, 27272 Sharjah, United Arab Emirates

[5] SHARE Berlin Institute, Chausseestraße 111, 10115 Berlin, Germany

[6] Department of Physiology, College of Medicine, King Saud University, 11451 Riyadh, Saudi Arabia

[7] Department of Biomechanics & Motor Behavior, College of Sport Sciences and Physical Activity, King Saud University, 11451 Riyadh, Saudi Arabia

[8] Exercise Physiology Department, College of Sport Sciences and Physical Activity, King Saud University, PO Box: 1949, 11451 Riyadh, Saudi Arabia

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Introduction

Hip fractures are a growing health problem of older adults worldwide, and the risk exponentially increases with advancing age in men and women [1]. The global annual incidence of hip fracture is over ten millions, which produces a significant burden on the healthcare system [2]. These numbers are primarily attributed to a growing aging population due to an increase in life expectancy. For example, the number of older adults aged 60 or above is expected to double by 2050. Hip fractures are a significant cause of functional dependency, disability, reduced quality of life, and a higher risk of mortality in old age [3]. In addition, they cause a considerable economic burden due to nursing and medical treatment of the patients [4].

An interface between skeletal muscle and bone is suggested so that patients with muscle wasting and weakness also exhibit osteoporosis [5]. Many older adults display an age-associated muscle degeneration, termed sarcopenia [6]. Specifically, they demonstrate muscle weakness, as elaborated by a reduced handgrip strength (HGS) [7]. The risk of osteoporosis and hip fracture is higher in patients with low HGS [5]. In addition, these patients also demonstrate reduced physical capacity in activities of daily living. For example, they have difficulty climbing stairs and are frequently bothered by a fear of falling down [8]. Thus, simple questions about household activities, including climbing stairs and falling down, may be useful in predicting future hip fractures.

Depression is common in patients following hip fractures due to a dependent lifestyle and reduced mobility [9]. It is also possible that depression may precede the onset of hip fracture and may possess predictive potential in diagnosing future hip fractures. Depression is a multifactorial disease and is partly due to age-associated comorbidities and neurodegeneration [9]. Most cases of hip fracture are due to an age-associated degeneration of osteocytes [10]. Thus, depression and hip fracture share a common etiopathology regarding age-associated decline. However, most relevant studies have investigated depression post-hip fracture [9], while the association of prior depression with future hip fracture remains poorly characterized. Several instruments are available to measure depression [11]. However, they show varying degrees of consistency and may not be globally relevant. A depression scale designed for a specific geographical region may demonstrate higher efficacy in evaluating depression. Euro-D depression scale is a frequently used and validated instrument to measure depressive symptoms among European adults [12]. However, its predictive potential for hip fracture remains elusive.

Several additional risk factors are associated with hip fracture [1, 13]. These include demography, lifestyle factors, and diseases of metabolic and degenerative pathologies. However, the prevalence of these risk factors is not consistent across populations and may vary across different cultures and countries. In addition, some risk factors are modified by age, which may affect their relevance to hip fracture. For example, the significance of malnutrition and previous osteoporotic fracture in predicting hip fracture diminishes in octogenarians compared to patients in their sixties and seventies [13]. It is possible that the development and/or worsening of other age-related diseases may affect the predictive potentials of these risk factors for hip fracture. For example, the prevalence of muscle wasting, hypertension, Alzheimer's disease (AD), diabetes mellitus, stroke, and cancer increases with age [14], which may compound the associations of various risk factors with hip fractures. Therefore, it is imperative to dissect the potential of individual risk factors in predicting future hip fractures by adjusting for age and comorbidities. However, such an investigation in a large population has not been performed. Lastly, the care for patients with hip fractures differs across various European countries, which may also affect the reporting of hip fractures and comorbidities [4]. A composite study across multiple European countries may help overcome this problem.

We investigated the efficacies of low HGS, depression, multiple demographic factors, and clinical diseases in predicting the future onset of hip fracture. This is a composite study of older adults from 15 European countries across 8 years using the standardized Survey of Health, Ageing, and Retirement in Europe (SHARE) dataset [15].

Materials and methods

The SHARE is a representative harmonized panel-data survey covering multiple European nations with the target population aged 50 and older [15]. SHARE collects data from the same individuals over multiple waves. The data collection process relies on computer-assisted personal interviews. These interviews encompass a wide range of domains, including demography, socioeconomic factors, living conditions, and both physical and mental health. The baseline data, which constitutes the background characteristics of the participants, were drawn from wave 5 of the SHARE survey, conducted in the year 2013. The follow-up surveys were from subsequent waves 6, 7, and 8, carried out in 2015, 2017, and 2019/2020, respectively. These successive waves provided valuable follow-up information on the participants' health, socioeconomic status, and other characteristics. It is important to note that the sample for the SHARE dataset includes 15 countries that were part of Wave 5. These countries are Austria, Germany, Sweden, Netherlands, Spain, Italy, France, Denmark, Switzerland, Belgium,

Israel, Czech Republic, Luxembourg, Slovenia, and Estonia. SHARE data is freely available for scientific purposes via the SHARE research data center website after individual registration.

Information on hip fracture was collected in various questions. At the first SHARE interview, respondents were asked if they ever had a hip fracture. In the follow-up interviews, respondents were asked if they had a hip fracture at the time of the interview or at any time since the previous interview. The question about the hip fracture since the last interview was used as follow-up information in waves 6–8. Only respondents who did not report a hip fracture at baseline (wave 5) and had follow-up information on hip fracture status in at least one of the subsequent waves (6–8) were included in this study. On average, about 4 years and 7 months elapsed between wave 5 and the last interview.

All covariates were derived from wave 5. The participants were categorized into age groups of 10-year intervals. The financial situation of the household was assessed by asking whether the household could make ends meet, with response options "with great difficulty," "with some difficulty," "fairly easily," and "easily."

The assessment of the quality of life was based on 12 items covering control, autonomy, self-realization, and pleasure (CASP-12), including three questions for each subcategory. The questions on the CASP-12 index were introduced by asking "I will now read a list of statements that people have used to describe their lives or how they feel. We would like to know how often, if at all, you experienced the following feelings and thoughts: often, sometimes, rarely, or never." The answers were graded with scores of 1 (often), 2, 3, and 4 (never). The CASP-12 composite index is the sum of the scores for each of the 12 indicators and thus ranges from 12 (minimum well-being) to 48 (maximum well-being). For analysis, the index was divided into three groups, including score ranges of 12 to 24 (low well-being), 25 to 36 (medium well-being), and 37 to 48 (high well-being).

HGS assessment was conducted using a calibrated handheld dynamometer (Smedley, S Dynamometer, TTM, Tokyo, 100 kg capacity). Prior to initiating the test, the interviewer demonstrated the proper procedure and obtained informed consent from the respondent. Medical exclusion criteria were swelling or inflammation in the hands, severe pain, recent injury, and recent hand surgery. Standardized instructions were provided to the participants. These instructions directed them to squeeze the dynamometer with maximal effort using both their left and right hands, with two repetitions for each hand performed alternately. The test could be performed in a standing position (upper arm parallel to the torso and lower arm at a 90° angle) or a seated position if necessary. Interviewers received harmonized training on the proper administration of the grip strength test. A previous study within the SHARE project identified that interviewer effects contribute to approximately 5–8% of the variance observed in HGS measurements [16]. For subsequent analysis, the highest value recorded from the four measurements (two per hand) was utilized [17]. A low HGS was defined based on the gender threshold of 27 kg for men and 16 kg for women according to the guidelines by the European Working Group on Sarcopenia in Older People (EWGSOP2) [18].

Mental health was assessed using the Euro-D depression scale, which is an additive index of the number of depressive symptoms reported by the respondents [19]. A total of 12 symptoms were asked, such as sadness, feelings of guilt, sleep problems, death wish, irritability, and loss of appetite. The scores for the Euro-D scale ranged from 0 to 12, with higher values indicating more depressive symptoms. For the analysis, we categorized the Euro-D score into groups of 0 (no depression), 1–3, 4–6, and 7–12 (high level of depression).

The presence of comorbidities was evaluated by investigating the reporting of high blood pressure, high blood cholesterol, diabetes mellitus or high blood sugar, cancer, AD, and stroke. This information was collected by showing a list of diseases to the respondents and asking if they had these conditions or if they had been diagnosed by a doctor. These items were summated into a simple multi-comorbidity index potentially varying between 0 and 6, which counts the number of morbidities.

Mobility was assessed by self-reporting whether respondents had difficulty climbing several flights of stairs.

For all analyses, we added the category "missing" to the variables making ends meet, quality of life, HGS, and Euro-D scores. This category was assigned to the individuals, who did not provide valid information for that question. This procedure prevented the sample from being reduced by "don't know" and "refuse" responses. Respondents who did not report hip fracture and were aged 50 or older at baseline and had follow-up information about hip fracture status in subsequent waves were included in this study.

Statistical analysis

The incidence of hip fractures for people initially without hip fractures was presented as the raw incidence rates based on the total number of new cases across the whole observation period after the initial base period. We also reported the incidence according to various subgroups, such as gender, age, socioeconomic status, and various health conditions. Lastly, the incidence in terms of odds ratios was estimated via regressions.

We used multiple regression analyses to identify personal characteristics affecting the future risk of hip fracture. We used a logit regression model due to the dichotomous nature of hip fracture (either the presence or absence of hip fracture

in each respondent), by applying the following regression equation specification.

$$\ln\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \epsilon$$

where π is the risk of hip fracture, $\pi/(1-\pi)$ is the odds of hip fracture, $X_1, X_2, \ldots, X_k$ are the k potential personal characteristics affecting the hip fracture risk, $\beta_1, \beta_2, \ldots, \beta_k$ are the effects of those characteristics, and ϵ is an error term. For instance, the relative risk of hip fracture for males (*m)* and females (*f*) is π_f/π_m and the odds ratio is e^{β_f}, while the effect of being female in percentage point terms is calculated using $\pi_f - \pi_m$. Estimated parameters are presented as odds ratios, such that values close to 1 indicate that the variable is not important in predicting the hip fracture, while values significantly above 1 indicate that the higher levels of the variable increase the risk of hip fracture. Further, odds ratios significantly below 1 mean that higher levels of the variable lead to a lower risk of hip fracture. Lastly, we have calculated each variable's effect as percentage points change (like for instance $\pi_f - \pi_m$) for calculating the risk of hip fracture (fractions), which are available from the authors upon request. The STATA software package 18.0 SE Standard Edition was used for the statistical analysis (Stata Statistical Software: Release 18. College Station, TX: StataCorp LLC). An alternative approach could have been the proportional Cox hazard model approach, which was not applied here since we only have a crude measure of time (years rather than months or weeks) and because the relatively very low incidence rates make the interpretation of odds-ratios much easier since they are approximately equal to relative incidence rates.

Results

Out of the 48,533 respondents (persons) at baseline in 2013, 1130 respondents subsequently reported having a hip fracture during the next 7 years till 2020. This implies a risk of hip fracture of 2.33% (Table 1). The risk of hip fracture was higher among women than in men. Among the study participants, 397 men reported hip fractures out of a baseline population of 20,962 (risk of hip fracture = 1.86%). Additionally, 733 women reported hip fracture out of a baseline population of 26,441 (risk of hip fracture = 2.70%). Next, we found an increasing risk of hip fracture with advancing age. For example, the study population aged 50–59 had a 0.76% risk of developing hip fracture. However, the risk increased to 1.21, 2.35, 4.65, and 7.24% for the respondents aged 60–69, 70–79, 80–89 and 90–99 years, respectively. We did not calculate the risk of hip fracture for the respondents aged 100 or above due to a small sample size.

Next, we found an inverse association between socioeconomic conditions and the risk of hip fracture. For example, the risk was 2.21% in respondents who easily managed to make ends meet. However, the risk increased to 2.86% among respondents who had great difficulty making ends meet. We observed a similar pattern of the quality of life with the risk of hip fracture. Thus, respondents with the lowest scores on CASP-12 had a 4.42% risk of developing hip fracture. Conversely, the highest score on CASP-12 was associated with a 1.92% risk of developing hip fracture. We also observed an inverse association between HGS and the risk of hip fracture. For example, we found a 4.5% risk of developing hip fractures among the respondents with HGS below the EWGSOP2 thresholds for both genders. Conversely, respondents with an HGS above the EWGSOP2 threshold exhibited a 2.00% risk of developing hip fracture.

We also found a positive association between depression and hip fracture. Thus, the respondents with depression had a higher risk of hip fracture (4.40%) than those without depression (1.61%). A higher level of multi-comorbidities is associated with higher hip fracture risks, but sample sizes are small for multiple comorbidities.

Next, we used regression models to estimate the potential effects of individual variables on hip fracture after controlling for other variables (Table 2). We found that female gender was associated with a higher risk of hip fracture with an odds ratio of 1.376, e.g., females were nearly 38% more likely than males to get a hip fracture. Similarly, advancing age was associated with a higher risk of hip fracture. Thus, compared to the respondents aged 50–59, those aged 60–69 had a 62% higher risk, while respondents aged 90 + years had a 671% higher risk of developing hip fractures. The relation between socioeconomic status and hip fracture appeared mild, as the respondents, who could make ends meet, easily had a 13.5% lower risk of hip fracture. Having the highest scores on the Euro-D depression scale was associated with a 46% higher risk of hip fracture than respondents without depression. Higher HGS is associated with 19% lower hip fracture risk. People with Parkinson's disease were 65% more likely to develop hip fracture. Finally, difficulties with climbing stairs were associated with a 29% higher risk of developing hip fractures.

Separate regressions for males versus females show that aging is particularly detrimental for female hip fracture risks, while this is less so for males. Additionally, for males only the mobility had the expected significant effect, while for females' wealth, HGS, depression, and Parkinson's disease were also important (in the expected directions).

Separate regressions were also made for 50–64 versus 65 + years old people. The pattern here generally reflects what was seen in the regression for all respondents pooled. One notable difference was that Parkinson's was not significant for the top age group but both significant and very

Table 1 Basic characteristics of the study population

		Control Count	HF Count	HF %	*p*-value
All		*47,403*	*1130*	*2.33*	
Gender	Male	20,962	397	1.86	0.000
	Female	26,441	733	2.70	
Age	50–60	5503	42	0.76	0.000
	60–69	17,178	211	1.21	
	70–79	15,159	365	2.35	
	80–89	7913	386	4.65	
	90–99	1650	126	7.09	
Foreign-born	No	42,085	1002	2.33	0.909
	Yes	5318	128	2.35	
Making ends meet	Great difficulty	3940	116	2.86	0.000
	Some difficulty	11,187	288	2.51	
	Fairly easily	13,705	292	2.09	
	Easily	17,649	398	2.21	
	Missing	922	36	3.76	
Quality of life	12–24	1060	49	4.42	0.000
	25–36	15,107	429	2.76	
	37–48	28,693	561	1.92	
	Missing	2543	91	3.45	
Hand grip strength	Below gender threshold	2973	140	4.50	0.000
	Above gender threshold	40,920	834	2.00	
	Missing	3510	156	4.26	
Euro depression scale	0	10,681	175	1.61	0.000
	1–3	24,118	526	2.13	
	4–6	8992	270	2.92	
	7–12	2432	112	4.40	
	Missing	1180	47	3.83	
Parkinson's disease	No	47,090	1109	2.30	0.000
	Yes	313	21	6.29	
Multi-morbidity	0	20,975	419	1.96	0.000
	1	15,645	387	2.41	
	2	7898	210	2.59	
	3	2491	92	3.56	
	4	363	20	5.22	
	5	31	2	6.06	
Difficulty with climbing several flights of stairs	No	35,887	671	1.84	0.000
	Yes	11,516	459	3.83	
Total		47,403	1130	2.33	

Characteristics are from wave 5, while Hip fracture data is from wave 6–8

Source: Own estimates based on the SHARE base, waves 5–8

much higher for the bottom age group, e.g., people aged 50–64 years had a 309% higher risk of hip fracture if they had Parkinson's compared to if they had not the disease.

An increasing hip fracture risk with increasing age was systematically observed for several characteristics (Table 3). For example, among gender-specific trends, the increase in the risk of hip fracture ranged from 1.01% (50–59 years old) to 3.69% (90 + years old) among men and 0.59% (50–59 years old) to 9.33% (90 + years old) for women. Similarly, respondents with low CASP-12 scores and high Euro-D scores also exhibited an increased risk of hip fracture with advancing age. The association between age and hip fracture was affected to varying degrees by other variables. For instance, among respondents with mobility difficulties, the risk of hip fracture was 1.47% for those aged 50–59, increased to 2.90% for those aged

Table 2 Regression model for the risk of hip fracture as odds ratio coefficients, based on the baseline characteristics in 2012 among European adults aged 50 or above

		Whole sample, all parameters			Only significant parameters, estimates				
		Estimate	95% CI		All	Males	Females	50–64 years	65 + years
Female		1.368***	1.205	1.554	1.376***			0.797	1.626***
Age	60–69	1.614**	1.156	2.252	1.618**		2.041**	1.519*	
	70–79	3.079***	2.228	4.256	3.084***	1.529**	4.563***		0.363***
	80–89	5.603***	4.040	7.771	5.615***	2.570***	8.740***		0.695***
	90–99	7.702***	5.332	11.126	7.705***	2.602***	13.24***		
Foreign-born		0.924	0.765	1.116					
Making ends meet	Some difficulty	0.933	0.745	1.167					
	Fairly easily	0.832	0.661	1.048	0.865*		0.862		0.844*
	Easily	0.986	0.783	1.240					
	Missing	0.833	0.562	1.234					
Quality of life	25–36	0.990	0.714	1.372					
	37–48	0.976	0.687	1.385					
	Missing	1.009	0.676	1.504					
Hand grip strength	Above gender threshold	0.863	0.707	1.052	0.814**		0.763**	0.477***	
	Missing	1.086	0.850	1.387					
Euro depression scale	1–3	1.155	0.968	1.377				1.413	
	4–6	1.316*	1.067	1.623	1.161*			1.602*	1.183*
	7–12	1.657***	1.251	2.195	1.462***		1.421**	2.445***	1.431**
	Missing	1.311	0.879	1.956					1.451*
Parkinson's disease		1.626*	1.032	2.562	1.653*		2.624***	4.094**	
Multi-morbidity		1.010	0.949	1.075					
Difficulty with climbing several flights of stairs		1.264**	1.099	1.454	1.288***	1.736***	1.165	1.890***	1.160*
N		48,533	48,533	48,533	48,533	21,359	27,174	22,934	25,599

Left out category: Male, age 51–59 years, not foreign-born, making ends meet with great difficulty, QoL 12–25, HGS below the gender-specific threshold, no Parkinson's disease, no difficulty climbing stairs

70–79%, and increased to 7.55% for those respondents aged 90 + years.

A higher depression level was frequently associated with a higher hip fracture risk independent of other variables (Table 4). Men without depression had a hip fracture risk of 1.47%, which increased to 3.18% among men with high depression. Similarly, the risks of hip fracture were 1.79% and 4.83% among women without or with high depression. Lastly, a higher HGS was associated with a lower risk of hip fracture, irrespective of gender and other characteristics (Table 5). For instance, among respondents without climbing difficulty, the hip fracture risks were 1.47% and 2.78% among men above and below the EWGSOP2 threshold, respectively. Further, the relevant risks for women were 1.90% and 3.78% for those above and below the EWGSOP2 threshold. Similarly, for respondents with climbing difficulty, the risks of hip fracture were 3.06% and 4.03% for men above and below the EWGSOP2 threshold for HGS. Lastly, the women with climbing difficulty exhibited risks of hip fracture of 3.25% and 6.15% for HGS above and below the EWGSOP2 threshold for HGS, respectively.

Although the focus here is not on country-level analysis, we nevertheless do not see huge differences in hip fracture risks between the included countries (Table 6). The lowest incidence was observed in the Netherlands, Denmark, and Belgium (0.90–1.63%), while the highest incidence was observed in Sweden, Spain, and Luxembourg (3.11–3.35%).

Discussion

This is the first composite study investigating the predictors of hip fracture in a large cohort of older adults from multiple European countries. A sample size of more than 48,000, including 1130 patients who subsequently developed hip fractures, strengthens the clinical relevance of our findings. After controlling for multiple variables, we found advanced age, female gender, poor socioeconomic status, low HGS, depression, and a frail state as critical predictors

Table 3 The incidence of hip fracture in percent by age groups among European adults aged 50 or above

		Age (years)					*N*
		50–59	60–69	70–79	80–89	90+	
Gender	Male	1.01	1.21	1.85	3.36	3.69	21,359
	Female	0.59	1.21	2.77	5.69	9.33	27,174
Foreign born	No	0.73	1.17	2.37	4.65	7.58	43,087
	Yes	0.93	1.60	2.22	4.69	3.40	5446
Making ends meet	Great difficulty	1.28	1.94	3.74	4.51	4.65	4056
	Some difficulty	0.96	1.26	2.64	4.49	9.59	11,475
	Fairly easily	0.72	1.11	2.01	3.97	7.03	13,997
	Easily	0.54	1.06	2.15	5.41	6.47	18,047
	Missing	0.00	2.20	3.01	4.84	6.02	958
Quality of life	12–24	2.97	1.86	5.13	5.48	8.74	1109
	25–36	1.01	1.56	2.70	4.62	7.02	15,536
	37–48	0.57	1.04	2.04	4.32	7.65	29,254
	Missing	0.97	1.16	3.03	6.31	5.18	2634
Hand grip strength	Below gender threshold	3.00	3.51	3.17	4.95	6.68	3113
	Above gender threshold	0.64	1.09	2.21	4.41	6.92	41,754
	Missing	2.33	2.22	3.59	5.73	7.94	3666
Euro depression scale	0	0.59	0.82	1.83	3.72	5.29	10,856
	1–3	0.62	1.18	2.11	4.49	6.41	24,644
	4–6	0.85	1.52	3.07	5.20	6.99	9262
	7–12	2.32	2.72	4.51	5.30	11.22	2544
	Missing	0.90	0.60	3.44	6.56	8.18	1227
Parkinson's disease	No	0.76	1.19	2.32	4.62	7.14	48,199
	Yes	0.00	8.70	6.19	6.35	5.00	334
Multi-morbidity	0	0.64	1.23	2.35	4.43	6.39	21,394
	1	0.72	1.13	2.44	4.34	7.66	16,032
	2	1.65	1.05	2.21	4.59	6.11	8108
	3	1.85	2.11	2.33	5.83	11.40	2583
	4	0.00	2.53	2.67	10.81	6.67	383
	5	0.00	0.00	0.00	16.67	0.00	33
Difficulty with climbing several flights of stairs	No	0.66	0.98	2.17	4.04	6.49	36,558
	Yes	1.46	2.37	2.90	5.51	7.55	11,975
Sample size		5545	17,389	15,524	8299	1776	48,533

of future incidence of hip fracture among European older adults. Conversely, the quality of life was not associated with hip fracture in our study pool.

As expected, there was an age-associated increase in the incidence of hip fractures in both genders from the sixth decade of life onward. This is primarily due to a gradual reduction in bone mineral density with age, which increases the risk of osteoporosis and hip fracture. Studies have shown that the occurrence of osteoporosis and hip fracture progressively increases after the age of 50. A progressively sedentary lifestyle and a concomitant decline in skeletal muscle with aging also contribute to reduced bone density and, consequently, an increasing risk of hip fracture. The incidence of hip fracture was higher among women than men, which is consistent with published literature. Interestingly, the gender disposition for women became prominent only after 70 years of age. Conversely, women between 50 and 70 did not exhibit a higher incidence of hip fracture than men. It is possible that the age-related degenerative processes are accelerated in women than in men from the age of 70 onward. A higher prevalence of comorbidities among women in their late sixties and beyond supports this observation [20]. Being a woman is an independent risk factor for fall and fall-related injuries due to a higher proportion of such events among women than in men [21]. Women also exhibit a faster loss of skeletal muscle than men during aging [22]. Some evidence also suggests poor postural control in women [23], which may contribute to falls and hip fractures. A loss of estrogen and its protective effects in advanced age may partly be responsible for these effects. Lastly, a relatively poor nutrition and sedentary lifestyle compared to men may compound the incidence of hip fractures in women [24].

Table 4 The incidence of hip fracture in percentage based on the performance on the Euro-D Depression Scale among European adults aged 50 or above

		Depression level					*N*
		0	1–3	4–6	7–12	Missing	
Gender	Male	1.47	1.76	2.51	3.18	2.92	21,359
	Female	1.79	2.44	3.10	4.83	4.75	27,174
Age	50–60	0.59	0.62	0.85	2.32	0.90	5545
	60–69	0.82	1.18	1.52	2.72	0.60	17,389
	70–79	1.83	2.11	3.07	4.51	3.44	15,524
	80–89	3.72	4.49	5.20	5.30	6.56	8299
	90–99	5.29	6.41	6.99	11.22	8.18	1776
Foreign-born	No	1.61	2.14	2.95	4.57	3.70	43,087
	Yes	1.67	2.11	2.66	3.50	4.42	5446
Making ends meet	Great difficulty	1.21	2.21	3.17	4.42	5.00	4056
	Some difficulty	1.55	2.18	3.08	4.44	3.72	11,475
	Fairly easily	1.70	1.88	2.50	4.59	3.72	13,997
	Easily	1.61	2.22	2.92	3.90	3.50	18,047
	Missing	1.57	3.90	4.09	5.10	3.90	958
Quality of life	12–24	0.00	0.86	4.28	4.97	10.71	1109
	25–36	2.12	2.50	2.83	4.44	3.07	15,536
	37–48	1.51	1.95	2.55	3.75	4.27	29,254
	Missing	1.71	2.82	5.73	3.05	3.67	2634
Hand grip strength	Below gender threshold	4.35	4.03	4.67	5.25	6.67	3113
	Above gender threshold	1.52	1.94	2.44	3.60	2.60	41,754
	Missing	1.10	3.74	5.36	6.12	4.17	3666
Parkinson's disease	No	1.62	2.12	2.85	4.29	3.81	48,199
	Yes	0.00	4.62	7.89	10.00	5.26	334
Multi-morbidity	0	1.44	1.73	2.99	4.06	2.90	21,394
	1	1.60	2.38	2.62	4.72	3.80	16,032
	2	2.19	2.41	2.72	3.54	4.38	8108
	3	2.23	3.10	3.83	5.07	6.61	2583
	4	0.00	4.27	6.14	10.91	0.00	383
	5	0.00	0.00	6.67	0.00	12.50	33
Difficulty with climbing several flights of stairs	No	1.48	1.76	2.32	2.78	3.64	36,558
	Yes	2.80	3.54	3.83	5.53	4.05	11,975
Sample size		5545	17,389	15,524	8299	1776	48,533

Together, these factors may explain the increasing incidence of hip fracture from 0.59% in quinquagenarian women to 9.33% in those aged 90 or above. Interestingly, the 10-year risk of hip fracture among British women closely mirrors these numbers and increases from 0.3 to 8.7% at ages 50 to 80 years [25].

Several studies have reported the predictive potential of HGS in functional recovery, ambulation capacity, and mortality of patients after hip fracture [26, 27]. It is previously recognized that a low HGS is associated with the future risk of hip fracture. However, the relevant studies investigated populations with specific comorbidities or had small sample sizes [28]. Conversely, such an association at the continental level was not previously dissected. Using the cutoff HGS values defined by EWGSOP2, we found that low HGS was significantly associated with future incidence of hip fracture in both genders. Interestingly, the incidence of hip fracture remained higher in patients with low HGS, irrespective of age. Thus, a low HGS appears as an independent risk factor for hip fracture in European adults. Several potential mechanistic links may exist between low HGS and future events of hip fracture. A weak muscle causes low mechanical loading of the bone, which may increase the risk of osteoporosis and hip fracture. Next, a low HGS is associated with a reduced ability to control postural balance and a higher risk of fall and fall-related injuries, including hip fracture. Lastly, patients with low HGS may also exhibit a frailty phenotype, a risk factor for hip fracture. In support of this, we observed a higher incidence of hip fractures in patients with low HGS and difficulties with climbing stairs.

Depression is a risk factor for various types of fractures, including hip fractures [29]. However, most studies

Table 5 The incidence of hip fracture in percentage based on gender and handgrip strength among European adults aged 50 or above

	Hand-grip strength:	Male			Female			*N*
		< 27	≥ 27	Missing	< 16	≥ 16	Missing	
Age	50–60	3.85	0.98	1.08	2.70	0.41	3.03	5545
	60–69	5.23	1.11	1.44	2.64	1.07	2.84	17,389
	70–79	1.97	1.86	1.72	3.88	2.52	4.85	15,524
	80–89	3.94	3.13	4.34	5.67	5.53	6.43	8299
	90–99	2.78	4.51	3.01	9.42	8.74	10.17	1776
Foreign born	No	3.23	1.74	2.53	5.69	2.21	5.26	43,087
	Yes	4.61	1.60	1.59	2.20	2.29	6.20	5446
Making ends meet	Great difficulty	3.92	1.53	3.55	5.25	2.29	7.32	4056
	Some difficulty	3.87	1.88	2.38	5.20	2.36	4.37	11,475
	Fairly easily	3.64	1.54	2.17	3.79	1.94	6.69	13,997
	Easily	2.35	1.78	1.70	6.64	2.30	3.96	18,047
	Missing	3.17	2.55	2.74	5.32	3.43	5.49	958
Quality of life	12–24	1.72	2.71	6.12	5.39	2.66	8.99	1109
	25–36	3.78	1.90	2.14	5.36	2.62	5.51	15,536
	37–48	3.12	1.57	1.55	3.85	2.01	4.23	29,254
	Missing	3.33	2.78	2.39	9.63	2.39	5.35	2634
Euro depression scale	0	2.44	1.48	0.00	6.45	1.59	1.97	10,856
	1–3	3.47	1.64	2.36	4.49	2.19	4.59	24,644
	4–6	3.11	2.32	3.85	5.36	2.50	5.90	9262
	7–12	5.05	2.99	2.52	5.31	3.81	7.69	2544
	Missing	5.56	3.37	2.48	7.69	1.93	6.04	1227
Parkinson's disease	No	3.38	1.72	2.36	5.20	2.19	5.23	48,199
	Yes	4.35	1.60	2.50	4.35	11.24	17.65	334
Multi-morbidity	0	3.54	1.54	1.38	5.45	1.89	4.34	21,394
	1	2.87	1.85	3.22	4.73	2.33	5.35	16,032
	2	3.00	1.71	1.60	5.20	2.61	5.95	8108
	3	5.00	1.91	3.31	5.19	3.63	7.85	2583
	4	6.90	6.14	5.00	9.09	1.82	6.52	383
	5	0.00	14.29	9.09	0.00	0.00	0.00	33
Difficulty with climbing several flights of stairs	No	2.78	1.47	1.66	3.78	1.90	4.32	36,558
	Yes	4.03	3.06	3.26	6.15	3.25	6.38	11,975
Sample size		1206	18,757	1396	1907	22,997	2270	48,533

investigating the potential of depression as a risk factor for hip fracture reveal inconsistent conclusions [29]. We found higher scores on Euro-D depression scales as independent risk factors for hip fracture. Interestingly, the risk of hip fracture increased with increasing scores on the Euro-D depression scales, validating the robust association between hip fracture and depression. Several potential mechanisms can explain this relation. First, depression increases serum levels of stress hormones, such as cortisol, and reduces anabolic hormones, including growth hormones and insulin growth factors, which reduce bone mineral density [30, 31]. Second, depression causes chronic systemic inflammation, which causes or contributes to osteoporosis [31]. Third, depression is associated with reduced physical activity and a sedentary lifestyle, negatively affecting bone health [29]. Lastly, depression causes poor postural control, gait instability, and reduced judgment and reaction time, which increase the risk of fall and fall-related injuries [29]. Together, these factors may provide a mechanistic explanation for higher depression and increased occurrence of hip fractures in European older adults.

Several comorbidities, including hypertension, diabetes mellitus, cancer, Alzheimer's disease, and stroke, were included in a summated index. However, we did not observe similar relations between these multi-comorbidities and hip fractures. Thus, the associations of these comorbidities with hip fracture appear to reflect systemic aging rather than the individual detrimental effects of comorbidities per se.

The major strengths of this study are its longitudinal design and the large representative sample size of most

Table 6 The incidence of hip fracture in percentage during 2012–2018 by country

	% with hip fracture	Sample size
Austria	2.00	3093
Belgium	1.93	4205
Czech Republic	2.21	4301
Denmark	1.63	3312
Estonia	1.99	4512
France	2.31	3244
Germany	2.43	4198
Israel	2.49	1808
Italy	2.24	3622
Luxembourg	3.11	1124
Netherlands	0.90	1673
Slovenia	2.10	2383
Spain	3.24	5064
Sweden	3.35	3466
Switzerland	2.57	2528
Total	2.33	48,533

European countries. The HGS and Euro-D depression scales are internationally standardized tools relevant to most clinical settings. The large sample size from multiple European countries minimizes the potential influences of diverse genetic, racial, and cultural profiles on the risk factors of hip fracture. The self-reporting nature of the SHARE dataset ensures its applicability in pre-clinical settings before high-risk patients are identified for clinical evaluation. However, this study has certain limitations. We did not measure bone mineral density, which is a direct assessment of bone quality and/or quantity. However, this study aims at pre-clinical settings. We did not differentiate between types of hip fractures, such as intracapsular, extracapsular, neck, and head of femur. Similar to any cohort study, the selective survival of the patients should be considered while interpreting the study findings. For example, men exhibit higher mortality than women following hip fracture [25], which may partly explain a higher incidence of hip fractures in women with advancing age. We did not measure the physical activities of the participants, which can affect their generalized health, including bone health. We did not account for recall bias, which may be a problem in older adults responding to questions about their past clinical events. Other clinical or subclinical comorbidities may be overlooked in this study. Data from some participants was collected with the help of an assistant, which may compromise the quality of the data.

Altogether, we report female gender, advancing age, depression, and low HGS as significant risk factors for developing hip fractures. We suggest a pre-clinical evaluation to identify high-risk patients before therapeutic strategies are developed to counter modifiable risk factors. Further studies may be required to mechanistically dissect the risk factors of hip fracture in an age- and gender-specific manner.

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Declarations

Author contribution Conceptualization: R.Q, M.H, A.K, A.K, F.A, F.F, A.A, A.M, M.A, and S.A. Data curation: M.H and F.F. Formal analysis: M.H and F.F. Funding acquisition: A.M, S.A. Investigation: R.Q, M.H, A.K, F.A, F.F, A.A, A.M, M.A, and S.A. Methodology: M.H and F.F. Project administration: R.Q, M.H, A.K, F.A, F.F, A.A, A.M, M.A, and S.A. Resources: R.Q, M.H, A.K, F.A, F.F, A.A, A.M, M.A, and S.A. Supervision: R.Q, M.H, A.K, F.A, F.F, A.A, A.M, M.A, and S.A. Validation: M.H, and F.F. Writing — original draft: R.Q. Writing — review and editing: R.Q, M.H, A.K, F.A, F.F, A.A, A.M, M.A, & S.A.

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Data availability The data is publicly available after application from https://share-eric.eu/. The access to data requires an individual-free registration followed by the acceptance of the SHARE Conditions and signing the SHARE User Statement. After acceptance of these documents, data can be downloaded using the personal ID and password.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests None

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