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# Increased risk of hip fracture among spouses—evidence of a homogamy effect

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## Abstract

**Summary** Spouses tend to share habits and therefore have an increased risk of same diseases. We followed all married couples in Sweden, born 1902 to 1942, in hospital records from 1987 to 2002, and found that individuals whose spouse had a hip fracture had an increased risk of hip fracture.

**Introduction** The purpose of this study was to determine whether spouses of hip fracture patients have an elevated risk of hip fracture.

**Methods** We performed a retrospective cohort study of all couples married for at least 5 years in Sweden and born between 1902 and 1942 ( $n = 904,451$ ) and all patients registered with a hip fracture ( $n = 218,285$ ) in the National Inpatients Register in Sweden from 1987 to 2002.

**Results** During the period 1987 to 2002 hip fractures occurred among spouses in 4212 married couples. The hazard ratio (HR) for hip fracture in a married woman following hip fracture in the husband was 1.11 (95 % confidence interval 1.07 to

1.16) compared to a woman whose husband did not have hip fracture. The corresponding HR for a married man was 1.20 (1.15 to 1.26) compared to a man whose wife did not have hip fracture. The risk was significantly elevated over the age range 60 to 90 years. The increased risk for hip fracture among spouses remained after adjustments for income, education, geographical latitude and urbanisation. In a common model with spouses and their siblings, the HR for spousal effect were 1.63 (1.01 to 2.64) and for sibling effect 2.18 (1.55 to 3.06) compared to married with spouse and sibling respectively without hip fracture.

**Conclusion** The novel finding of an increased risk for hip fracture among spouses provides evidence indicating that there is a homogamy effect due to common social and lifestyle factors but could also be due to assortative mating.

**Keywords** Assortative mating · Hip fracture · Homogamy · Osteoporosis

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## Introduction

Osteoporosis is a major public health problem with an estimated prevalence of 27.6 million individuals in the EU in 2010, and worldwide, the condition causes more than 8.9 million fractures annually [1]. The most serious fracture type is hip fracture, which almost always requires hospitalisation and surgery. Sweden has one of the highest hip fracture incidence rates, with 401 per 100,000 incidence hip fractures in men and women annually, although the annual incidence has declined since 1996 for women, but not for men [2, 3].

Hip fracture is associated with increased mortality and commonly gives rise to long-standing disabilities with high health care costs [1, 4, 5]. In women from Sweden, the median age for hip fracture is 82 years and for men 79 years [3]. Risk

factors for hip fracture include age, female sex, height, early menopause, low bone mineral density (BMD), low body mass index (BMI), obesity, previous fragility fracture, hip fracture in parents, hip geometry, genetic factors and lifestyle factors such as diet, reduced sunlight exposure, smoking, alcohol and physical inactivity [1, 2, 6–13].

Spouses tend to share lifestyle factors and environmental exposures such as smoking, alcohol consumption, diet, physical activity level and UV radiation, and persons with the same habits, personality and/or mental disorders tend to seek to each other [14–18]. There is also a positive correlation between spouses regarding body height, weight and the level of education attained [18]. When spouses share the same diseases more frequently than expected, this suggests an environmental sharing, whilst a disease correlation between siblings indicates heritable and environmental effects [14]. Meyler et al. summarised in a systematic review 103 health concordance research articles and found concordance among spouses for physical as well as mental diseases [19]. A large cross-sectional study of 8386 married couples, aged 30 to 74 years, reported an increased risk for peptic ulcer, hypertension, diabetes, depression, asthma or hyperlipidaemia among married couples [20]. Another study on familial risk for common diseases showed a disease correlation between spouses, which suggests that environmental factors play an important role in the development of diseases among spouses [14]. Although the increased risk of disease correlations between spouses might be explained by environmental sharing, in which individuals tend to share and expose themselves to similar conditions, it could also be due to assortative mating. We hypothesised that the risk of hip fracture would be increased in married women and men whose partner had a record of hip fracture.

## Methods

### Cohort

We studied all patients with hip fracture ( $n = 218,285$ ) in the National Patient Registry in Sweden from 1987 to 2002. This register was linked with the Multigeneration Register, the Register of Cause of Death, the National Census Register from 1970 to 1990 and the Register of the Total Population in Sweden. We included all married couples in Sweden ( $n = 904,451$ ), born between 1902 and 1942 who had been married at least 5 years before baseline 1987 (divorces accounted for). Couples that divorced during the follow-up period were considered as still married. The correlation in age between spouses was 0.90, and for 77 % of the married couples in our study, the age difference was at most 5 years.

In a sub-analysis, we compared the spousal effect on risk of hip fracture to the sibling effect on risk of hip fracture. We

only had information on sibling relations for persons born 1932 to 1942, up to the age of 66. This allowed us to include previous hip fracture in sibling as an effect variable in the models for 280,754 married persons (167,076 women and 113,678 men) born 1932 to 1942 with at least one sibling ( $n = 600,814$ ). If one or more events of hip fracture were found in siblings during the period 1987 to 2002, we only selected the earliest hip fracture. If the person at risk had a hip fracture, we only selected the hip fracture in sibling that occurred before the risk persons' hip fracture. In this way, a new effect variable was defined as previous hip fracture in sibling.

### Covariates

The relationship between hip fracture risks was analysed taking into account the following covariates: age, sex, time of marriage, calendar year for fracture, income, education, geographical latitude and level of urbanisation of place of residence. The age of the individuals was calculated for each observation period, consisting of approximately 60 days. Data on income were available from the years 1991, 1996 and 2002, and the highest value (inflation-adjusted) was used. Then, quintiles were calculated separately in each separate 10-year birth year group. Data on income were missing for 3.4 % of women and 7.5 % of men. Level of education was categorised on a seven-point scale, where 1 is <9 years in school and 7 is postgraduate education. We defined low education as being in level 1 for those born before 1930 and being in level 1 or 2 for those born 1930 or later. Shorter education was more common in earlier years. Education level was missing completely in the cohorts born 1902 to 1910, and data were missing for 2 to 5 % in younger cohorts. In total, missing data were found in 6.4 % of women and 10.8 % of men. Latitude and urbanisation level were available for all subjects. Urbanisation was categorised on a six-point scale, where 1 is >200,000 inhabitants per municipality and 6 is <15,000 inhabitants. Due to large proportion of missing data for income and education, a sensitivity analysis was performed using just the cohort with value on income and education when comparing the spouse effect adjusted and not adjusted for income and education.

### Outcomes

We studied admissions to Swedish hospitals for hip fracture between January 1987 and December 2002. The source comprised the National Swedish Register (the patient register of the National Board of Health and Welfare), which registers each hospital admission on a continuous basis. A unique personal identifier permitted the tracking of individuals for multiple admissions. The database included all patients discharged from the hospital according to the disease category and surgical procedure. Registration is a legal requirement, is

backed by financial inducement and has an accuracy that exceeds 90 % for surgical admissions [21]. To identify all patients with hip fracture, we used the International Classification of Diseases (ICD), ninth and tenth revisions. Each patient included in the register was required to have ICD codes for hip fracture and ICD codes for surgical procedures related to hip fracture: ICD-9 codes for diagnosis 820A–D, 820W, 820X and surgery procedure codes 8200–8219, 8413, 8414 or ICD-10 codes for diagnosis S720–S724, S727–S729 and surgical procedure codes NFB and NFJ. All cases were documented by age and sex.

### Statistical analysis

The married population was followed for 17,961,850 person-years. Each person was followed from January 1, 1987 until December 31, 2002 in the Swedish Hospital Discharge Register to capture the first occasion of a potential hip fracture and date of death. The admission date was assumed to be the fracture date. Only the first hip fracture during the time period 1987 to 2002 was recorded. Data from the entire Sweden were not available before 1987.

An extension of Poisson regression model was used to study the relationship between the risk of hip fracture with age, sex and previous hip fracture in spouse (as a time-dependent covariate) [22]. In contrast to logistic regression, the Poisson regression utilises the length of each individual's follow-up period. The observation period of each participant was divided in intervals of 2 months. The result is presented as hazard ratios (HRs) with 95 % confidence interval (CI), and the result from this model is comparable to that derived from a Cox proportional hazard model. The Poisson regression model was stratified by age and sex.

The analysis is made with the main effect variable as a time-dependent covariate, where the condition studied can be changed during follow-up. When describing HR between a person with and without a spouse with hip fracture, one person can contribute to both conditions for different period of times of follow-up.

### Results

During the period 1987 to 2002, a first hip fracture was found in 88,902 married couples. A hip fracture occurred in both spouses in 4212 married couples (Table 1). Notably, in seven couples, a hip fracture occurred in both partners within 3 days. The mean age for sustaining a hip fracture was 78.4 years for married women and 79.7 years for married men. In married couples, men were on average 2.6 years older than the women, in the time period 1987 to 2002. During the 16-year follow-up, 1914 wives sustained a hip fracture before the husband,

**Table 1** Number of hip fractures in husband (column) and wife (row) at different ages

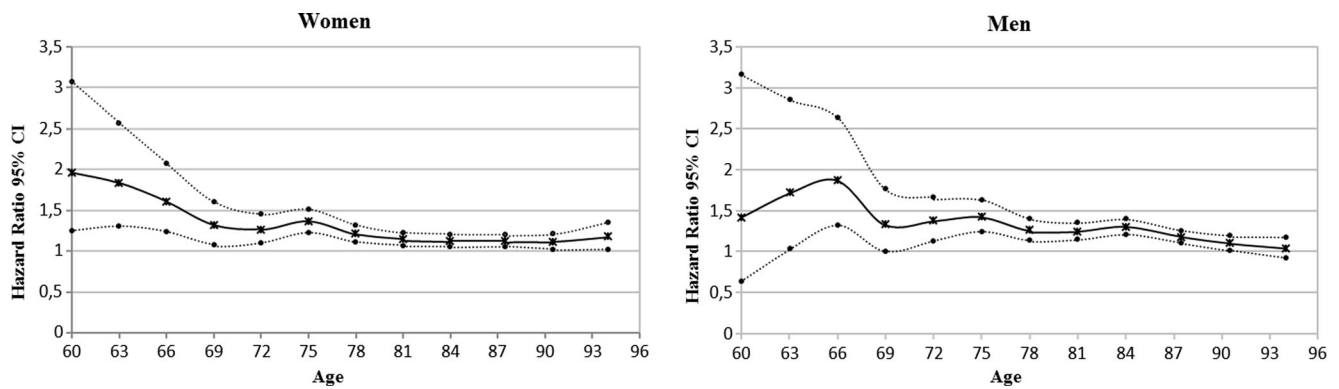
	<60	60–<70	70–<80	80–<90	90–<100	Total
<60	5	13	8	1	0	27
60–<70	5	46	131	84	4	270
70–<80	2	65	550	765	72	1454
80–<90	0	15	401	1477	291	2184
90–<100	0	0	22	190	65	277
Total	12	139	1112	2517	432	4212

whereas 2291 husbands sustained a hip fracture before the wife.

Some of the married couples could have divorced during the follow-up period. Most of the divorces occurred in younger ages with low risk for hip fracture, and only 2.5 % of all the couples divorced during the 16-year follow-up. A sensitivity analysis excluding risk time after time of divorce did not change the results. The shorter risk time due to this resulted in a decrease of 0.8 % in the number of hip fracture in women and 1.1 % in men.

Our analyses revealed an increased risk of hip fracture in both men and women aged 60 to 95 years if their spouse previously had sustained a hip fracture (Fig. 1). There were few married couples under 60 years of age where both had suffered a hip fracture (Table 1). The HR for hip fracture in a married woman after her husband sustained a hip fracture was 1.11 (1.07 to 1.16) compared to risk time for a woman whose husband did not have a hip fracture. The corresponding HR for a married man was 1.20 (1.15 to 1.26) compared to a man whose wife did not have a hip fracture. When including only spouses under the age of 90 years, the age-adjusted HR for hip fracture was higher among married women (1.12, 1.07 to 1.17) and men (1.27, 1.21 to 1.34) compared to spouses without hip fracture. The HR was significant over the age range 60 to 90 years, with the exception of men aged 60 to 70 years (Table 2). Women aged 60 to 70 years and men aged 70 to 80 years were at highest risk of sustaining a hip fracture if their spouse had sustained a hip fracture (Table 2). There was a significant association between the risk for hip fracture and the covariates age, income, latitude and urbanisation, but not education (Table 3). The increased risk for hip fracture among spouses remained mainly unchanged after adjustments for age, income, education, latitude and urbanisation (Table 2).

The difference between being married less than 25 years and being married more than 25 years was non-significant in all age intervals. In the age interval 65 to 75 years, there was a non-significant 19 % increase in HR (1.19, 0.76 to 1.86) for hip fracture in spouses married less than 25 years, whilst spouses married more than 25 years had a 34 % increase in HR (1.34, 1.08 to 1.67) for hip fracture compared to spouses without hip fracture. In the age interval 75 to 85, there was a



**Fig. 1** Hazard ratio for hip fracture after hip fracture in spouse for women and men aged 60 to 95 years compared to married women and men with a spouse with no hip fracture. Adjusted for age and calendar year

29 % increase in HR (1.29, 1.08 to 1.52) for hip fracture among spouses married less than 25 years and 36 % increase in HR (1.36, 1.26 to 1.47) for hip fracture among spouses married more than 25 years compared to spouses without hip fracture. In the age interval 70 to 90 years, spouses married less than 25 years had a 19 % increase in HR (1.19, 1.03 to 1.36) for hip fracture, whilst spouses married more than 25 years had a 28 % increase in HR (1.28, 1.21 to 1.35) for hip fracture compared to spouses without hip fracture.

In the sub-analysis of married men and women ( $n = 280,754$ ) with siblings ( $n = 600,814$ ) born 1932 to 1942, we observed 2308 hip fractures among the married by following them for 4.39 million risk years, a total incidence risk of 0.5 cases per 1000 risk years. Among the married, 2514 had a spouse with previous hip fracture and 4081 had a sibling with previous hip fracture. Among the married with a hip fracture event, 37 had a sibling with previous hip fracture and 22 had a spouse with previous hip fracture; none had both a spouse and a sibling with previous hip fracture. Siblings had an increased risk of sustaining a hip fracture when another sibling had sustained a hip fracture when compared to siblings without hip fracture and spouses with or without hip fracture (Fig. 2). HR for previous hip fracture in

sibling was 2.13 (95 % CI 1.54 to 2.95) compared to married with siblings without hip fracture. The age-adjusted HR for hip fracture in sisters was 2.22 (1.76 to 2.79) and in brothers 1.36 (1.03 to 1.80) compared to married with sisters and brothers respectively, without hip fracture. HR for previous hip fracture in spouse in this sub-analysis was 1.64 (95 % CI 1.04 to 2.58) compared to spouses without hip fracture. In a Poisson model with both previous hip fracture in spouse and previous hip fracture in siblings adjusted for gender, age and latitude, HR was 1.63 (1.01–2.64) for spousal effect and 2.18 (1.55–3.06) for sibling effect when comparing married persons with spouse/sibling with previous hip fracture to married persons with spouse/sibling without previous fracture.

## Discussion

We present a novel finding on spousal concordance for hip fracture, using data from the entire Swedish married population (904,451 married couples) aged 45 to 100 years. A hip fracture occurred in both spouses in 4212 married couples, and the HR for hip fracture in men was 1.20 (1.15 to 1.26)

**Table 2** Hazard ratio (HR) for hip fracture when spouse also has sustained a hip fracture

Age interval	Women		Men	
	Number of fractures	HR (95 % CI)	Number of fractures	HR (95 % CI)
Adjusted for age and calendar year				
60–70	7173	1.29 (1.01–1.66)*	3402	1.18 (0.80–1.75)
70–80	21,970	1.26 (1.16–1.37)*	11,899	1.34 (1.20–1.49)*
80–90	24,577	1.07 (1.01–1.13)*	16,075	1.25 (1.18–1.33)*
Adjusted for age, calendar year, latitude, urbanisation, education and income				
60–70	7082	1.42 (1.11–1.80)*	3278	1.22 (0.84–1.78)
70–80	20,440	1.27 (1.17–1.38)*	10,697	1.33 (1.19–1.48)*
80–90	16,587	1.08 (1.01–1.15)*	9364	1.31 (1.22–1.41)*

\* $p < 0.05$



**Table 3** Covariates' risk for hip fracture

Covariates	Women HR (95 % CI)	Men HR (95 % CI)
Age per year (60–91)	1.16 (1.15–1.16)*	1.17 (1.16–1.17)*
Low education (yes/no)	1.02 (1.00–1.04)	0.98 (0.95–1.01)
Income (low to high)	0.94 (0.94–0.95)*	0.90 (0.89–0.91)*
Latitude (south to north)	1.06 (1.05–1.07)*	1.08 (1.07–1.10)*
Urbanisation (urban to rural)	0.98 (0.97–0.98)*	0.95 (0.94–0.96)*

Hazard ratio (HR) per one step in each variable

\* $p < 0.05$ 

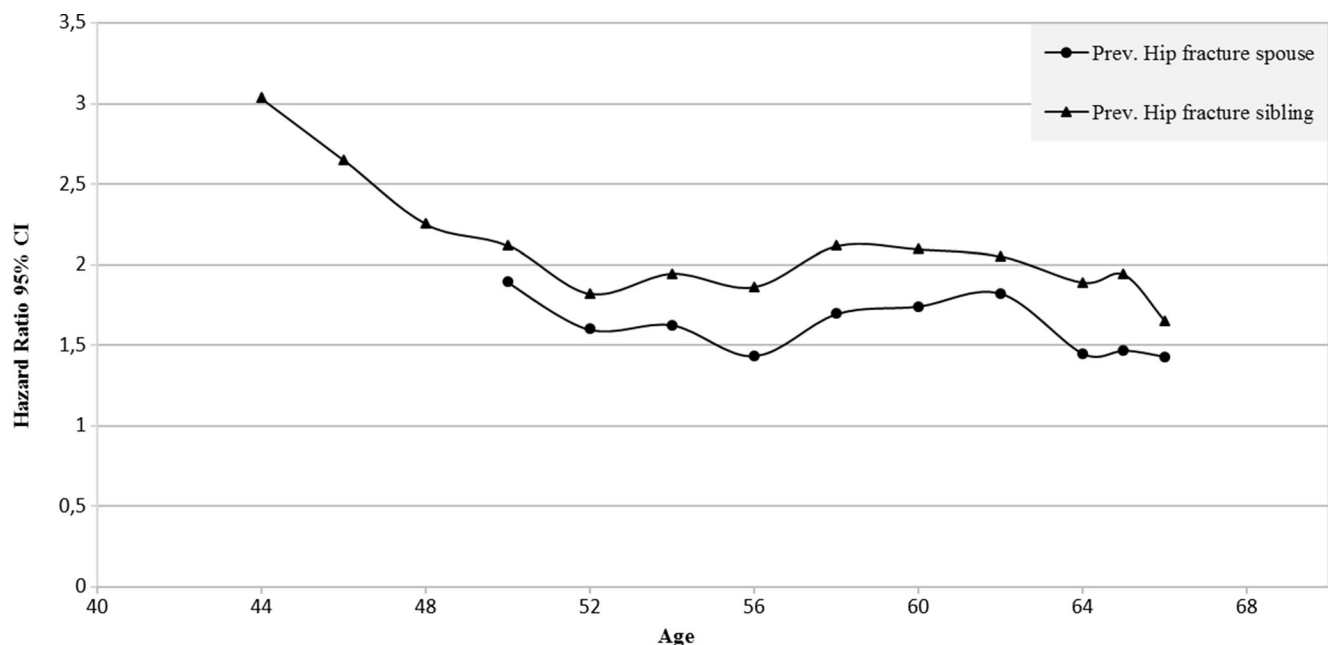
and in women 1.11 (1.07 to 1.16) after a hip fracture also in the spouse. The results were unaffected when adjusted for age, latitude, education, income and urbanisation. To our knowledge, a spousal effect on hip fracture risk has not been presented earlier. The underlying mechanisms for the finding of a homogamy effect are complex and might be a combined effect of assortative mating and shared lifestyle patterns over a long marriage. Our results might contribute not only to the understanding of mechanisms for hip fracture but also for the importance of interventional measures in both spouses.

Our study also showed that men and women have an increased risk of hip fracture if their sibling had sustained a hip fracture. Family history is a strong risk factor for hip fracture [7]. The effect of parental history of diseases for the risk of disease in first-degree relatives has been assumed to be mainly related to genetic factors [7, 23]. In a study of women and men from seven prospectively studied cohorts, a total of 34,928 women and men, 6 % reported a maternal history of hip fracture. The relative risk for hip fracture with a maternal history of hip fracture

was 2.27 (95 % confidence interval 1.47 to 3.49) [7]. There is a genetic component for peak bone mass most apparent in lumbar spine [24, 25]. Most studies of genetic effects have used BMD techniques and cannot distinguish between cortical bone and trabecular bone or bone size and differences in bone density. There is an obvious heredity both for variation in bone density and for fractures [7]. However, parents and children also share the same socioeconomic conditions and environmental factors which might have effects on disease risk [23]. On the other hand, the socioeconomic and environmental circumstances are even more likely to be similar in older married couples who have lived together for a more extended time period compared to parents and children. We showed in a Poisson model including both married couples and their siblings up to the age of 66 years that the homogamy effect was independent of the sibling effect on hip fracture risk.

### Assortative mating

Individuals tend to prefer to marry those who are similar (homogamy) in terms of educational level, religion and other socioeconomic factors. Studies have indicated assortative mating for body height, BMI, physical activity, alcohol intake and smoking [18, 26, 27]. All these factors have been associated with the risk of hip fracture [1, 6]. Taller women tend to marry taller men, and height is a proposed risk factor for later hip fracture with approximately 40 % increased risk per increased standard deviation of height at the age of 25 [6, 12, 13, 18]. A genome-wide genetic study provided evidence for genetic assortative mating in American spouses. However, the genetic similarity only accounted for about 10 % of the assortative mating by education level [28].

**Fig. 2** Family effect on hip fracture by age based on siblings and married people born 1932 to 1942. Adjusted for age and calendar year

## Spousal (homogamy) effect on lifestyle factors and diseases

Married people tend to share lifestyle factors like physical activity, nutritional intake and use of alcohol and tobacco and same living environment such as stairs and carpets that can increase the risk of falling. A meta-analysis showed a substantial spousal concordance for smoking (odds ratio 3.25, 95 % confidence interval 2.94 to 3.59) [29]. Bone mineral density was evaluated in a study of 104 spouses at age above 50 years and married for approximately 40 years. There was no spousal concordance for Z-score of BMD or in loss of bone density. However, there was an obvious concordance between partners concerning weight, height, BMI, muscle strength, physical activity, 25-hydroxyvitamin D<sub>3</sub>, caloric intake and smoking [30]. Married couples living at high latitudes, as in Scandinavia, are exposed to a shorter period of vitamin D production in the skin. Elderly people at rural areas tend to have lower risk for hip fracture compared to urban areas [31]. Married couples have similar nutritional intake with impact on gut microbiota. Recent studies have indicated a possible impact of microbiota for several diseases like osteoporosis, atherosclerosis and diabetes [32–34]. Spouses have a doubled risk for peptic ulcer, which might partly be explained by spousal concordance in *Helicobacter* colonisation [20]. Spouses share lifestyle factors over many years especially in ages above 70 years in which there is a high incidence of fractures, cardiovascular and cancer. A meta-analysis showed spousal concordance for most risk factors in cardiovascular disease such as hypertension, smoking, diabetes and obesity. Authors therefore argue that interventions to reduce cardiovascular risk factors should be addressed to both members of a marital couple [29]. A study of the importance of family factors and cancer was performed in the Swedish Family-Cancer Database (FCD) comprised of almost 15 million people coordinated with the Multigeneration Register. The results showed a significant familial risk for almost all types of cancer including colorectal, stomach, oesophagus, lung, urinary bladder and skin. The standardised incidence ratio (SIR) was higher also in first-degree relatives. However, SIR for oesophagus cancer was approximately 3.0 in spouses and 2.64 in first-degree relatives. The population attributable fraction for familial cancer was estimated to 6 % [23]. Genetic factors and lifestyle factors often occur together. Studies have shown not only a strong heritability of smoking but also assortative mating for smoking among spouses explaining high SIRs for lung cancer both for first-degree relatives and spouses [23]. Measures for preventing cancer, such as stopping smoking and sun protection, should be advocated both for relatives and married couples. A meta-analysis of spousal concordance for diabetes showed a 26 % increased diabetes risk after spousal history of diabetes. Authors argue for health interventions with increased physical activity and nutritional intervention among married couples to prevent

diabetes [35]. A recent study of 29,096 individuals with celiac disease in Sweden showed an increased risk for other autoimmune disease among both first-degree relatives and spouses indicating that in addition to genetic factors, also environmental factors contribute to the risk of autoimmunity [36].

## Strengths and weaknesses of the study

Strengths of our study include study size, the long follow-up period and the fact that hip fracture is a reliable registered diagnosis. Our study includes all married couples born 1902 to 1942, registered in the National Population Register 1982 to 1986. This register was linked to the National Swedish Register of Discharge Hospital Care to receive information on orthopaedic diagnosis and procedure. Information on marriage, hip fracture and death has high validity in the registers. All individuals with hip fracture are admitted to the hospital and therefore also registered in the discharge register [1]. Another strength is that we are able to compare our result with other married couples.

A limitation of our study is that we followed individuals for a maximum period of 16 years, which means that a hip fracture that occurred before 1987 or after 2002 would not have been included in the analysis. A weakness may be that some married couples in fact do not live together. This also applies to the control group. For the oldest patients, there are missing data on education and income. However, the results from incomplete and complete data were similar when analysing the risk for hip fracture among spouses adjusted for all covariates. In the sub-analysis of siblings, we could only include hip fracture in persons up to the age of 66 years. The results might therefore differ somewhat for older persons.

## Possible explanations and implications

We suggest that one of the reasons why spouses have an increased risk of hip fracture is due to their environmental sharing of overall lifestyle and exposures. Individuals who have lived together for some time tend to share habits like smoking, alcohol intake, physical inactivity and sharing the same diet, which also are risk factors for hip fracture [1]. The mean age for hip fracture in Sweden is 83 years. This means that most women who sustain a hip fracture after hip fracture in husband have been married for 50 years or more. A Swedish study showed an increased risk for hip fracture following low-level cadmium exposure, mainly from bread and smoking. The cadmium burden is increasing with age [37]. Spouses also have an increased risk of several diseases such as hypertension, lung cancer, chronic obstructive pulmonary disease (COPD) and mental disorders [14]. A large Swedish study of familial cancer showed an increased risk for several cancer forms not only among siblings but also, to a lesser extent, among spouses [23].

Another explanation might be assortative mating, which means that people prefer a partner with largely similar

characteristics as themselves. A Dutch study of almost 12,000 couples showed that there were no significant differences in resemblance between partners when older couples, who had been together for a long time, were compared to younger couples [38]. A study of Swedish married couples showed a correlation for both height and weight [18]. Low BMI, obesity and increased height are risk factors for hip fracture [2, 6, 12, 13]. Choice of spouse might also be genetically determined. A study of non-Hispanic white US adults provided evidence of genetic assortative mating. Comparing spouses to two individuals chosen at random showed that spouses are genetically more similar [28].

## Conclusion

We show for the first time an increased risk for hip fracture among spouses and how this varies with age. The risk among spouses was, however, lower compared to the hip fracture risk among siblings. The proposed homogamy effect not only could be attributed to shared social and lifestyle factors but could also be due to assortative mating. In line with the intervention measures against cancer, cardiovascular diseases and diabetes, spouses should be included in the intervention strategies to prevent hip fractures.

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## Compliance with ethical standards

**Conflicts of interest** None.

**Ethical approval** We received de-identified data registers from the Swedish National Board of Health and Welfare. This study has been approved by the regional ethics committee in Gothenburg and Malmö/Lund, Sweden.

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