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*Original Article*

# Lifetime Risk of Hip Fractures is Underestimated

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**Abstract.** Estimates of lifetime risk of osteoporotic fracture have assumed that mortality rates do not change. Since mortality in the elderly is decreasing in all regions of the world we assessed the effect of this on lifetime risks for hip fracture using Sweden as a reference country. Lifetime risks of hip fracture at the age of 50 years were 4.6% and 13.9% in men and women respectively, assuming all survive to current average life expectancy. Estimates increased to 8.1% and 19.5% when based on present mortality and to 11.1% and 22.7% respectively based on predicted mortality. We conclude that lifetime risks of hip fracture have been considerably underestimated.

**Keywords:** Hip fracture; Lifetime risk; Mortality

## Introduction

Estimates of the size of the problem of osteoporotic fracture commonly utilize lifetime risks. These take account of the incidence of fracture as well as life expectancy in specific communities. Such estimates are useful for descriptive purposes, but also are important in the assessment of the health economic burden and in designing intervention strategies [1,2]. Lifetime risks of hip fracture in women vary markedly between communities. In women aged 50 years or more they vary from 11% to 18% depending in part on differences in incidence and differences in life expectancy [3–7]. Whereas the incidence of hip fracture (and in some instances other osteoporotic fractures) has been well characterized in many countries, estimates of hip fracture risk using life expectancy have been less critically evaluated.

Several approaches have been taken to estimate lifetime risk from life expectancy. A commonly used strategy is to use average life expectancy, usually from the age of 50 or 60 years, as a base calculation [3,5,6,8]. A comparable approach, useful for comparing rates in different communities, is to assess the risk to a given age, for example the age of 80 years [9]. Both methods assume that all individuals live to the age of 80 years or to the average life expectancy. An additional approach is to model cohorts from different ages [7,10]. This has the advantage of taking into account the variations in mortality for a given cohort.

All these methods make assumptions that mortality is not changing. In all regions of the world, however, life expectancy is increasing [11]. Thus, the mortality rate of 80-year-olds today is likely to be greater than the mortality of 50-year-olds when they become 80 years old in 30 years time. Increasing life expectancy is a worldwide phenomenon. It is particularly marked in Asia but more modest in Europe. The impact of secular trends in life expectancy on estimates of osteoporotic fracture risk has not been evaluated. In this paper we assess, using a conservative scenario, the impact of these different estimates of mortality on lifetime risks of hip fracture using Sweden as a reference country.

## Methods

Data on the number of hip fractures (ICD 820) were obtained from the Swedish Patient Register for 1987 to

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1994. Information in the years 1987 to 1993 was used to identify patients sustaining a hip fracture in 1994 who had previously suffered a hip fracture. The annual incidence of a first hip fracture and of a second fracture was estimated from the fracture history between 1987 and 1994. The estimate assumed that no hip fractures occurred before 1987. This may have marginally overestimated the incidence of a first hip fracture. Only hip fractures that were treated surgically by nailing were counted. This underestimates the incidence by 5% [12], but avoids second operations from failed surgery, and the underestimate is likely to offset the overestimate due to the inclusion of some second hip fractures. Incidence rates were computed in 5-year intervals using the mean population size of Sweden in 1994. The mean population size was taken as the average of the population size in 5-year intervals at the beginning and at the end of the year. The incidence of first fracture was 30% higher than that determined from a survey of the entire population of Malmö that involved a review of all radiographs and hospital records [13].

Future mortality rates were computed for each year of age from Poisson models (see Appendix) using the Swedish Patient Register and the Statistical Year Book (Table 1). Excess mortality was computed separately for a first and subsequent hip fracture. Excess mortality estimates were comparable (within a few percent) to independent estimates computed for 1991/1992 (B. Jonsson, personal communication 1997). Calculations of future mortality over the lifetime of the male and female population (deaths/1000) were assumed to be reduced each calendar year by the same rate, but with a rate that was different for different ages. The rate of change was estimated as a continuous function of age by use of the maximum likelihood method for the period 1987 to 1993 (see Appendix). After $t$ years the estimated mortality rate at the age of $y$ years is equal to the present mortality rate at the age of $y$ years times Exp $[(-0.0505 + 0.00048y)t]$ for men and Exp $[(-0.0351 + 0.00033y)t]$ for women. The official estimates of the future population use a somewhat simpler model than we did, namely a reduction in mortality for each year by the same rate irrespective of age, but yield essentially comparable results. Actual and predicted mortality for Sweden are shown in Fig. 1.

**Table 1.** Mortality by age in Sweden (1994) in the general female community and in the year following hip fracture

| Age (years) | Population mortality (/1000) | Hip fracture mortality (/1000) | Excess mortality (risk ratio) |
|---|---|---|---|
| 50 | 2.25 | 35.86 | 15.9 |
| 55 | 3.07 | 25.75 | 8.4 |
| 60 | 5.06 | 54.79 | 10.8 |
| 65 | 8.23 | 39.35 | 4.8 |
| 70 | 15.53 | 97.08 | 6.3 |
| 75 | 25.8 | 80.84 | 3.1 |
| 80 | 47.1 | 199.45 | 4.2 |
| 85 | 83.4 | 166.08 | 2.0 |

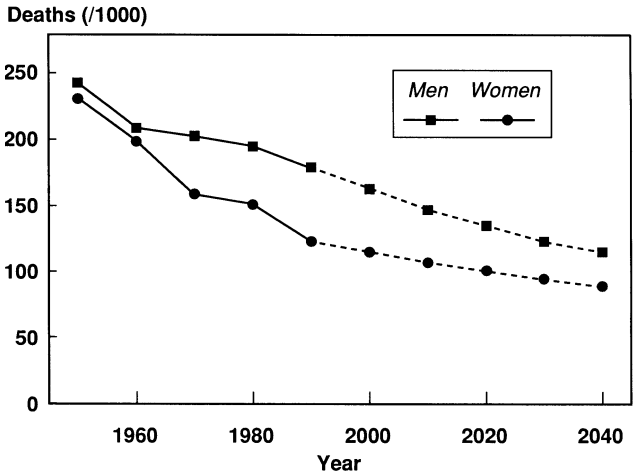


**Fig. 1.** Deaths per 1000 according to calendar year in individuals aged 85–95 years in Sweden. The *continuous lines* denote observed values and the *dotted lines* the predicted death rate in accordance with the model used.

In addition to secular trends in mortality, there is evidence that a secular trend in hip fracture rates is occurring in many countries [2]. In most countries the age- and sex-specific incidence appears to be increasing, though they appear to have levelled off in Sweden, the UK and the USA [13–15]. We modeled an increasing or decreasing incidence of hip fracture by 1% per annum in order to assess the impact of secular trends on lifetime risks.

## Results

In Sweden the average life expectancy (1988) at the age of 50 years in women is 32.41 years. If it is assumed that all women at the age of 50 years live to 82.41 years, the remaining lifetime risk of hip fracture is 13.9% (Table 2). The lifetime risk at the age of 50 years in men in 4.6% due to a lower life expectancy and a lower age incidence than women. Lifetime risk remains relatively stable with age until the age of 70 years because the

**Table 2.** Lifetime risks of hip fracture (%) in men and women by age using three methods of computing life expectancy

| Age (years) | A | | B | | C | |
|---|---|---|---|---|---|---|
| | Men | Women | Men | Women | Men | Women |
| 50 | 4.6 | 13.9 | 8.1 | 19.5 | 11.1 | 22.7 |
| 55 | 4.7 | 14.4 | 8.2 | 19.6 | 10.6 | 22.3 |
| 60 | 4.9 | 15.1 | 8.3 | 19.8 | 10.1 | 21.9 |
| 65 | 5.4 | 15.7 | 8.4 | 19.9 | 9.8 | 21.5 |
| 70 | 6.0 | 16.5 | 8.6 | 20.1 | 9.6 | 21.2 |
| 75 | 6.6 | 18.1 | 9.0 | 20.2 | 9.6 | 20.9 |
| 80 | 8.1 | 18.7 | 9.7 | 19.6 | 10.1 | 20.0 |
| 85 | 9.0 | 18.7 | 10.5 | 18.7 | 10.7 | 18.9 |

A, all individuals survive to average life expectancy for the age shown; B, based on current mortality rates; C, based on predicted mortality rates.

influence of decreasing life expectancy with age is matched by the increasing incidence of fracture. Thereafter, lifetime risks increase due to the dominating effect of fracture incidence with age (column A, Table 2).

Risks are markedly influenced by estimating the mortality in cohorts, where the average age of death is the same as above but account is taken of the variation in mortality around this average. In women the lifetime risk increases to 19.5% at the age of 50 years (column B, Table 2), an increment of 5.6% in lifetime risk. The effect is more marked in men than in women and the average lifetime risk at the age of 50 years is nearly doubled at 8.1% compared with the first method of assessment. The effect of using cohorts rather than average life expectancy on lifetime risks is greater the younger the age and, by the age of 80 years, lifetime risks are comparable with both methods of analysis.

When account is taken of trends in life expectancy, even higher estimates of lifetime risk are obtained in both men and women, an effect that is more marked the younger the age (column C, Table 2; Fig. 1). The trend for increasing lifetime risks after the age of 70 years was not apparent using this assumption since improvements in life expectancy will affect the younger individuals of the cohorts more markedly than those who are elderly today.

The burden of hip fracture to communities is underestimated by these calculations irrespective of the model used, since there is a significant increase in risk of a second hip fracture. The number of hip fractures expected in 100 individuals during their lifetime is shown in Table 3.

There is a marked effect of secular trends on lifetime risks in men and women. Assuming that mortality continues to decrease in the same way as it did between 1987 and 1997, lifetime risks of hip fracture at the age of 50 years increase from 11.1% to 17.0% in men and from 22.7% to 34.9% in women if an increase in age-specific risk is assumed (Table 4). As might be predicted, the effects are less marked in the elderly. Conversely lifetime risks would be markedly decreased if age- and sex-specific risks decreased in the future.

**Table 3.** Expected numbers of hip fractures (per 100 individuals) by age to the end of life, using two methods to compare life expectancy

| Age (years) | B | | C | |
|---|---|---|---|---|
| | Men | Women | Men | Women |
| 50 | 9.6 | 23.6 | 13.1 | 27.3 |
| 55 | 9.7 | 23.7 | 12.5 | 26.9 |
| 60 | 9.8 | 24.0 | 11.8 | 26.4 |
| 65 | 9.8 | 24.0 | 11.4 | 25.8 |
| 70 | 10.0 | 24.1 | 11.1 | 25.4 |
| 75 | 10.4 | 24.1 | 11.0 | 24.9 |
| 80 | 11.2 | 23.0 | 11.6 | 23.5 |
| 85 | 12.1 | 21.6 | 12.3 | 21.8 |

B, based on current mortality rates; C, based on predicted mortality rates.

**Table 4.** Lifetime risk of hip fracture (%) in men and women by age, using two methods of computing life expectancy

| Age (years) | Increasing age- and sex-specific risk | | | | Decreasing age- and sex-specific risk | | | |
|---|---|---|---|---|---|---|---|---|
| | B | | C | | B | | C | |
| | Men | Women | Men | Women | Men | Women | Men | Women |
| 50 | 12.4 | 30.0 | 17.0 | 34.9 | 6.3 | 15.0 | 8.4 | 17.4 |
| 55 | 11.9 | 29.1 | 15.4 | 32.9 | 6.6 | 15.8 | 8.4 | 17.8 |
| 60 | 11.6 | 28.4 | 14.2 | 31.2 | 6.9 | 16.5 | 8.4 | 18.2 |
| 65 | 11.3 | 27.6 | 13.3 | 29.8 | 7.3 | 17.3 | 8.4 | 18.6 |
| 70 | 11.1 | 26.9 | 12.5 | 28.4 | 7.7 | 18.0 | 8.5 | 19.0 |
| 75 | 11.3 | 25.9 | 12.1 | 26.8 | 8.3 | 18.6 | 8.8 | 19.3 |
| 80 | 11.9 | 24.3 | 12.3 | 24.9 | 9.1 | 18.5 | 9.5 | 18.9 |
| 85 | 12.5 | 22.3 | 12.9 | 22.5 | 10.1 | 18.0 | 10.3 | 18.2 |

B, based on current mortality rates; C, based on predicted mortality rates.
Hip fracture incidence is assumed either to increase by 1% per annum in both men and women (left-hand columns) or to decrease by 1% per annum in both men and women (right-hand columns).

**Table 5.** Predicted number of hip fractures by calendar year in Sweden

| Year | A | | B | | C | |
|---|---|---|---|---|---|---|
| | Men | Women | Men | Women | Men | Women |
| 1990 | 3821 | 10433 | 3821 | 10433 | 3821 | 10433 |
| 1995 | 4042 | 11105 | 4248 | 11671 | 3844 | 10561 |
| 2000 | 4196 | 12063 | 4635 | 13325 | 3794 | 10910 |
| 2005 | 4270 | 12396 | 4957 | 14391 | 3673 | 10661 |
| 2010 | 4323 | 12481 | 5274 | 15229 | 3535 | 10208 |
| 2015 | 4432 | 12513 | 5683 | 16047 | 3447 | 9733 |
| 2020 | 4623 | 12732 | 6232 | 17160 | 3420 | 9418 |
| 2025 | 4866 | 13320 | 6893 | 18869 | 3423 | 9370 |

A, based on predicted mortality rates; B, as above with an increase in age- and sex-specific risk of 1% per annum; C, as above with a decrease in age- and sex-specific risk of 1% per annum.

The effects of different assumptions on the burden of hip fractures in Sweden are shown in Table 5. It is estimated that there were 14254 hip fracture in Sweden in 1990. Assuming no change in the age- and sex-specific incidence of hip fractures, the number of hip fractures in 2025 will rise to 18186, an increase of 28%. There is a marked effect of changes in the secular trend. If age- and sex-specific incidence increases by 1% per annum the expected number of hip fractures in 2025 would increase by 42%. A 1% decrease over this term would decrease the burden by 30%.

## Discussion

A common method for estimating lifetime risk of hip fracture assumes that all deaths occur at a given age. Our results suggest that the lifetime risks of hip fracture are very considerably underestimated using this method.

Moreover, even where current mortality figures are utilized considerable underestimates still occur. On the reasonable assumption that life expectancy will continue to improve, as it has done over the past several centuries, the future burden of hip fracture in all communities is grossly underestimated. In Sweden the expected number of hip fractures will increase by 28% between 1990 and 2025 based on predicted mortality (Table 5). It is relevant to note that these estimates have been undertaken utilizing data from Sweden. This has the advantage of robust information on both hip fracture and mortality, but Sweden is a country where expected increases in life expectancy are average for the developed world but modest compared with many other regions of the world [16]. Thus, the underestimate utilizing current models will be more marked in the developing world.

Assumptions concerning the secular trend in hip fracture rates have a marked impact on lifetime risks and hence the future burden of hip fractures in the community. The sensitivity analysis that we chose ($\pm 1\%$ change in age- and sex-specific rates) is nevertheless very conservative on a worldwide basis. Indeed, in most communities estimates range from 1.0% to 3.3% per annum [17]. If annual increases of 2.5% are applied to worldwide estimates of future fracture excluding North America and Northern Europe, where rates have stabilized, then the lifetime risks worldwide would be comparable to the present risk in Sweden [16]. On this basis the number of hip fractures in 2025 would be 16 million compared with a current estimate (1990) of 1.2 million.

The underestimate of mortality and its consequences on hip fracture risk have important consequences for screening and treatment strategies in osteoporosis. The ability of bone mineral density to identify individuals at risk from osteoporosis depends in part on the gradient of risk for hip fracture associated with decrements in bone density, but also the lifetime risk of fracture [2]. High-risk strategies will be undervalued where the lifetime risks of fracture are artifactually low. Additionally, the long-term impact of interventions in the community is likely to be underestimated, which in turn has its health economic consequences. These data suggest that the size of the problem of hip fracture and to some extent other osteoporotic fractures has been grossly underestimated, and account needs to be taken of this in strategic development.

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## Appendix. Statistical Methods

The aim of the present study was to calculate the lifetime risks and the expected numbers of hip fracture from a certain age to the end of the life. In order to perform the calculations we needed hazard functions of hip fracture and of death under different conditions. The estimation of those functions was also an important aim of the article.

The hazard functions of the first fracture and of the second fracture are denoted $f_1(t)$ and $f_2(t, v)$, respectively, where $t$ is the current age and $v$ is the age at the first fracture ($t < v$). The hazard function of death before the first fracture is denoted $d_1(t)$ and the hazard function of death after the first fracture but before the second one is denoted $d_2(t, v)$, where $t$ and $v$ have the same meaning as before. The probability of escaping the first fracture from the age *START* to the age $T$ or to the death is given by the following expression. It assumes that no fracture has occurred before the age *START*.

$$\int_{START}^{\tau} d_1(t)\exp(-\int_{START}^{t}(f_1(u)+d_1(u))du)dt + \exp(-\int_{START}^{\tau}(f_1(z)+d_1(z))dz)$$

The last term of the expression is the probability of being alive without fracture at age $T$ and the first term is the probability of dying at different ages $t$ without a previous fracture.

The probability of exactly one fracture during the age interval (*START*, *T*), provided there is no fracture before the age *START*, is

$$\int_{START}^{\tau} f_1(t)\exp(-\int_{START}^{t}(f_1(u)+d_1(u))du)x$$

$$\left\{\int_{t}^{\tau} d_2(v,t)\exp(-\int_{t}^{v}(f_2(z,t)+d_2(z,t))dz)dv + \exp(-\int_{t}^{\tau}(f_2(y,t)+d_2(y,t))dy)\right\}dt$$

The part of the expression on the first line corresponds to the event that the individual has a fracture at the age $t$ and neither dies nor has a fracture before that. The first part of the second line corresponds to the event that the individual dies at the age $v$ without any event (second fracture before death) before the age $v$, and the last part of the second line corresponds to the event that the individual is alive at the age $T$ without a second fracture.

For some calculations it was assumed that the death hazard and the fracture hazard change by calendar years, and that generalization goes somewhat further than indicated by the expressions above.

Let $p_i$, $i = 0, 1, 2$, denote the probability of an individual having exactly $i$ fractures during their life. Only in rare cases will an individual have more than two hip fractures during their life. Thus, in this article the probability of having three or more fractures was set at zero. That assumption implied that $p_2 = 1 - p_0 - p_1$. The expected number of fractures was $p_1 + 2p_2 = 2(1 - p_0) - p_1$, which could be calculated by use of the two given expressions.

Using the Swedish Patient Register the following numbers were calculated for each 5-year age cohort and sex:

A Mean population size of Sweden 1994. The mean population size is the mean between the number at the beginning and at the end of the year (approximately equal to the number in the middle of the year).
B Number of individuals alive at the middle of 1994 with exactly one hip fracture since the start of 1987.
C Number of individuals alive at the middle of 1994 with more than one hip fracture.
D Number of individuals with a first hip fracture during 1994.
E Number of individuals with a second hip fracture during 1994.

The first fracture rate $f_1(t)$ per 1000 was approximately determined as $1000 \times D/(A - B - C)$.

A simplification: In the calculations we have assumed that $f_2(t, v)$, the hazard of a new fracture provided that there was a previous one at the age $v$, did not depend on $v$. The rate of the second fracture was approximately estimated as $100 \times E/B$.

As the death rate $d_1(t)$ before the first fracture we used as an approximation the death rate of the normal population. For some of the calculations we needed an estimation of the future death rate. By use of a Poisson model (Breslow and Day) the change in the death rate was estimated by the determination of a factor $\exp[(\beta_0 + \beta_1 t)s]$ with which the rate will be changed. The variable $t$ is the age and $s$ is the number of years from now to the time in the future. The change in the death rate was, according to the model, different at different ages.

The death rate after the first fracture was estimated by use of a Poisson model as a function of current age, time since fracture and calendar year. The death rate was $\exp[\beta_0 + \beta_1$ Min(Age, 65) $+ \beta_2$ Max(0,Age$-$65) $+ \beta_3$ Min(Period since last fracture, 1) $+ \beta_4$ Max (0, Min(Period . . . $-$1, 3$-$1)) $+ \beta_5$ Max(Period . . . $-$3,0) $+ \beta_6$ (Calendar year $-$ 1986)].

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