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ORIGINAL ARTICLE

An estimate of the worldwide prevalence and disability associated with osteoporotic fractures

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Abstract
Objective The aim of this study was to quantify the global burden of osteoporotic fracture worldwide.
Methods The incidence of hip fractures was identified by systematic review and the incidence of osteoporotic fractures was imputed from the incidence of hip fractures in different regions of the world. Excess mortality and disability weights used age- and sex-specific data from Sweden to calculate the Disability Adjusted Life Years (DALYs) lost due to osteoporotic fracture.
Results In the year 2000 there were an estimated 9.0 million osteoporotic fractures of which 1.6 million were at the hip, 1.7 million at the forearm and 1.4 million were clinical vertebral fractures. The greatest number of osteoporotic fractures occurred in Europe (34.8%). The total DALYs lost was 5.8 million of which 51% were accounted for by fractures that occurred in Europe and the Americas. World-wide, osteoporotic fractures accounted for 0.83% of the global burden of non-communicable disease and was 1.75% of the global burden in Europe. In Europe, osteoporotic fractures accounted for more DALYs lost than common cancers with the exception of lung cancer. For chronic musculo-skeletal disorders the DALYs lost in Europe due to osteoporosis (2.0 million) were less than for osteoarthrosis (3.1 million) but greater than for rheumatoid arthritis (1.0 million).
Conclusion We conclude that osteoporotic fractures are a significant cause of morbidity and mortality, particularly in the developed countries.

Keywords Disability-adjusted life-years · Hip fracture · Mortality · Noncommunicable diseases

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Introduction

Several studies have quantified the global burden of osteoporosis as judged by the current and predicted number of hip fractures [1–3]. The most recent study also quantified the global morbidity arising from hip fractures. In this study there were an estimated 1.31 million new hip fractures in 1990, and the prevalence of patients with disability due to hip fracture was estimated at 4.48 million [3]. There were 1.75 million disability-adjusted life-years (DALYs) lost, representing 0.1% of the global burden of disease worldwide and 1.4% of the burden for women from the established market economies.

Attention has focussed on hip fracture morbidity because epidemiological information is more widely available for the hip than for other sites of osteoporotic fracture. However, fractures in other sites contribute significantly to the burden of osteoporosis, particularly in younger individuals in whom osteoporotic fractures at sites other than the hip are much more common. For example, it has been estimated that in Swedish women between 50 and 54 years old, such fractures account for six times the morbidity of that arising from hip fracture [4, 5]. The aim of the present study was to estimate the global burden of all osteoporotic fractures and to compare the burden with that for other noncommunicable diseases.

Methods

The approach used was to compute the DALYs as used by the World Bank and the World Health Organization [6, 7]. This integrates the disability and life-years lost due to osteoporotic fracture. Demographic estimates of population numbers and mortality were taken from the Global Burden of Disease 2000 project [8], and the information was applied to 17 subregions of the world. For the purpose of presentation, the subregions were collapsed to the seven major regions shown in Table 1.

Incidence of fracture

The incidence of hip fracture was computed for the world regions for men and women age 50 years or more in 5-year age intervals, when possible, from the year 1990 onwards [9]. Hip fracture rates were supplemented with recent data from Thailand [10] and Cameroon [11]. Country-specific data were used for the subregions as shown in Table 1. When more than one estimate was available for a subregion, a mean value was used. When no estimate was available for a subregion, we used data from other subregions within the same global burden of disease region.

Table 1 Regional epidemiological analysis categories for Global Burden of Disease (GBD) 2000 project: GBD regions and 17 subregions

GBD region		Mortality stratum	World Health Organization member states
Africa	AFRO	D	Algeria, Angola, Benin, Burkina Faso, **Cameroon**, Cape Verde, Chad, Comoros, Djibouti, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome And Principe, Senegal, Seychelles, Sierra Leone, Somalia, Sudan, Togo
	AFRO	E	Botswana, Burundi, Central African Republic, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Uganda, United Republic of Tanzania, Zambia, Zimbabwe
Americas	AMRO	A	**Canada**, **United States**
	AMRO	B	Antigua and Barbuda, **Argentina**, Bahamas, Barbados, Belize, Brazil, **Chile**, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, Uruguay, **Venezuela**
	AMRO	D	Bolivia, Ecuador, Guatemala, Haiti, Nicaragua, Peru
Eastern Mediterranean	EMRO	B	Bahrain, Cyprus, Iran (Islamic Republic of), Jordan, **Kuwait**, Lebanon, Libyan Arab Jamahiriya, Oman, Qatar, Saudi Arabia, Syrian Arab Republic, Tunisia, United Arab Emirates
	EMRO	D	Egypt, Iraq, Morocco, Yemen
Europe	EURO	A	Andorra, Austria, Belgium, Croatia, Czech Republic, **Denmark**, **Finland**, **France**, **Germany**, **Greece**, **Iceland**, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, **Netherlands**, **Norway**, **Portugal**, San Marino, Slovenia, **Spain**, **Sweden**, **Switzerland**, **United Kingdom**
	EURO	B1	Albania, Bosnia and Herzegovina, Bulgaria, Georgia, Poland, Romania, Slovakia, the former Yugoslav republic of Macedonia, **Turkey**, Yugoslavia
	EURO	B2	Armenia, Azerbaijan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan
	EURO	C	Belarus, Estonia, **Hungary**, Kazakhstan, Latvia, Lithuania, Republic of Moldova, Russia Federation, Ukraine
Southeast Asia	SEARO	B	Brunei Darussalam, Indonesia, Malaysia, Philippines, Singapore, Sri Lanka, **Thailand**
	SEARO	D	Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan
Western Pacific	WPRO	A	**Australia**, **Japan**, New Zealand
	WPRO	B1	**China**, Mongolia, **Republic of Korea**
	WPRO	B2	Cambodia, Lao People's Democratic Republic, Myanmar, Vietnam
	WPRO	B3	Cook Islands, Fiji, Kiribati, Marshall Islands, Micronesia (Federated States of), Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu

Empirical data are available for those countries shown in boldface (see Methods).

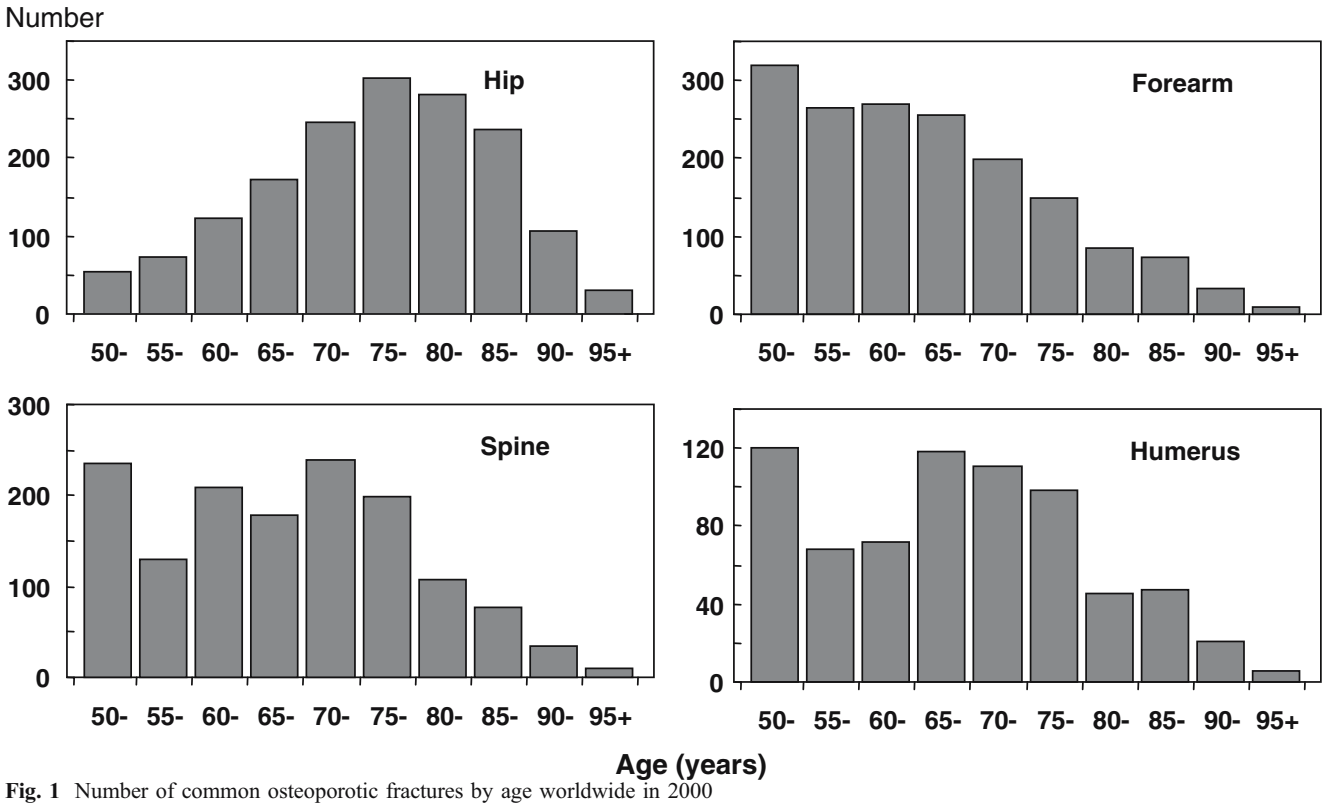

Fig. 1 Number of common osteoporotic fractures by age worldwide in 2000

For example, no estimate was available for AFRO E, so the data from Cameroon (AFRO A) were used for the subregions.

Other fractures associated with osteoporosis ("osteoporotic fracture") comprised fractures of the forearm, humerus, spine, pelvis, other femoral fractures, tibia and fibula (in women), ribs, clavicle, scapula, and sternum [5]. Because few systematic data are available, we assumed that the ratio of the incidence of hip to that of other osteoporotic fractures was similar to that observed in Sweden. For example, between the ages of 50 and 54 years, hip fractures accounted for 4.7% and 3.8% of all osteoporotic fractures in men and women, respectively. These figures rise progressively with age, so that between the ages of 80 and 85 years, hip fractures account for 25.9% and 35.6% of all osteoporotic fractures in men and women [5]. We assumed, therefore, that these ratios of incidence would apply elsewhere. The adequacy of this assumption is not known worldwide, but the available information suggests that the pattern of fractures is similar in the Western world and Australia despite differences in incidence [12–15]. Also, within the United States, the pattern appears to be similar amongst blacks and whites. For example, in white women age 65–79 years, the ratio of hip, distal forearm, and proximal humeral fractures is 43%, 38%, and 19%, respectively. For black women the ratio is 45%, 36%, and 18%, respectively [16].

Years of life lost

Mortality after hip fracture was computed from the excess mortality after hip fracture and compared with that of the general population in each region [8]. Excess mortality by age and gender used data from Sweden [17] and in the base case assumed, therefore, that in each region the age-specific relative risk of death after hip fracture compared with that of the local population was similar to that of Sweden. The excess mortality after hip fracture is, however, partly due to comorbidity. An analysis from the Swedish population suggested that approximately 25% of deaths associated with hip fracture were causally related to the hip fracture event itself [18], and this assumption was used for the base case. Excess mortality has also been documented for other

Table 2 Estimated number of fractures (in thousands) worldwide at the sites shown in men and women in the year 2000 (*F/M* female-to-male ratio)

Site of fracture	Men	Women	Total	Percentage	F/M
Hip	490	1,137	1,627	18.2	2.3
Forearm	332	1,328	1,660	18.5	4.0
Spine	554	862	1,416	15.8	1.6
Humerus	178	528	706	7.9	3.0
Other sites	1,909	1,641	3,550	39.6	0.9
Total	3,463	5,496	8,959	100	1.6

Table 3 Estimated number of fractures (in thousands) worldwide by age and gender in the year 2000

Age range (years)	Hip			Forearm			Spine			Humerus			Other			All sites		
	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total
50–54	30	24	54	72	247	319	140	95	235	47	73	120	350	192	542	639	631	1,269
55–59	38	36	74	84	181	265	66	63	129	17	50	68	517	164	681	722	494	1,216
60–64	58	67	124	60	210	270	97	112	209	26	47	72	237	149	387	478	584	1,062
65–69	68	104	172	70	186	256	60	118	178	23	95	118	276	215	491	497	719	1,216
70–74	80	166	246	14	184	198	80	158	239	33	78	111	195	204	400	403	791	1,194
75–79	81	221	302	15	135	150	54	145	199	16	82	98	93	258	351	259	840	1,099
80–84	68	213	281	9	77	86	33	74	107	8	37	45	143	180	323	261	581	842
85–89	48	189	237	5	68	73	18	60	77	6	41	47	67	174	241	143	531	674
90–94	17	89	106	2	32	34	6	28	34	2	19	21	24	82	106	51	250	301
95+	4	27	30	0	10	10	1	8	10	0	6	6	5	24	29	11	75	86
Total	490	1,137	1,627	332	1,328	1,660	554	862	1,416	178	528	706	1,909	1,641	3,550	3,463	5,496	8,959

osteoporotic fractures, including those of the spine and proximal humerus, although not for forearm fractures [19, 20]. For fractures other than hip fractures, we assumed that the excess mortality attributable to the fracture would be proportional to the disutility occasioned at each fracture site. Disutilities (the cumulative loss of quality of life) were taken from Kanis et al. [4]. For example, the disutility in women age 70–74 years from hip fracture is 1.202 and for spine, humerus, and forearm fractures is 0.790, 0.305, and 0.08, respectively. For the same age, the excess mortality due to hip fracture is estimated at 25/100,000 of the population. Thus, the estimated excess deaths for spine fracture at the same age would be 16/100,000, for humerus fractures would be 6/100,000, and for forearm fractures would be 0.5/100,000 of the population.

The years of life lost due to osteoporotic fractures was computed from the number of fractures and the premature mortality. The years of life lost were age-weighted for the purposes of computing DALYs. The weighting assigns a greater value to a year of young adult life than to a year in the life of a child or an elderly person [7]. For example, a life-year valued at 1.0 at the age of 55 years is valued at 0.8 at the age of 60 years and 0.7 at the age of 70 years. Methods are given in detail elsewhere that describe the construction of specific software models for the computations [7, 21]. The weighting was removed in a sensitivity analysis.

Nonfatal outcomes

Disability due to fractures was computed from estimates of quality of life-adjusted life-years (QALYs) lost using methods previously described [5]. The disability weight, expressed as a fraction, describes a range of disutility between death (=1) and perfect health (=0). The cumulative utility lost (disutility) was used to compute the average "duration of disease" using methods previously described [3]. The "prevalence" of osteoporotic fracture in the year 2000 was computed from the population size, the "duration of disease," and the incidence of fracture and mortality rates for individuals with and without osteoporotic fractures. The computation assumes that the fracture and death hazards do not change with time. The years of life lost due to disability was calculated from the cumulative disability in the year 2000 due to new nonfatal osteoporotic fractures, and that of survivors from osteoporotic fractures that occurred before the year 2000.

Disability-adjusted life-years

The DALY was computed from the sum of the years of disabled life in survivors and the life-years lost due to premature mortality, using a 3% discount [3, 7].

Table 4 Estimated number of fractures (in thousands) at the sites shown in men and women age 50 years or more in 2000 by World Health Organization regions

Region	Hip	Spine	Forearm	Humerus	Other	All sites	Percentage
Africa	8	12	16	6	33	75	0.8
Americas	311	214	248	111	521	1,406	15.7
Southeast Asia	221	253	306	121	660	1,562	17.4
Europe	620	490	574	250	119	3,119	34.8
Eastern Mediterranean	35	43	52	21	109	261	2.9
Western Pacific	432	405	464	197	1,039	2,536	28.6
Total	1,627	1,416	1,660	706	3,550	8,959	100

Results

The estimated number of new osteoporotic fractures for the year 2000 was 9.0 million, of which 1.6 million were at the hip, 1.7 million were at the forearm, and 1.4 million were clinical vertebral fractures (Fig. 1, Table 2). Seventy percent of hip fractures occurred in women. The respective figures for forearm, spine, and humerus fractures were 80%, 58%, and 75% in women. Fractures at other sites were more common in men than in women. Overall, 61% of osteoporotic fractures occurred in women, so the female-to-male ratio was 1.6.

The peak number of hip fractures occurred between the ages of 75 and 79 years in both men and women, but for all fractures, the peak number occurred between 50 and 59 years and decreased with age (Table 3).

The greatest number of fractures was in Europe, followed by the Western Pacific region, southeast Asia, and the Americas. Collectively, these regions accounted for 96% of all fractures (Table 4). The Americas and Europe accounted for 51% of the burden worldwide.

The prevalence of fracture, defined as the number of individuals suffering disability, is shown by region in Table 5. Fracture sufferers were estimated at 56 million worldwide, with a female-to-male ratio of 1.6. As expected from the pattern of incidence, the prevalence was greatest in Europe.

The total DALYs lost was 5.8 million (Table 6). Of these, 51% were accounted for by fractures that occurred in Europe and the Americas. The burden was greater in women than in men, and the former accounted for 64% of DALYs. Hip fractures accounted for 0.82 million DALYs in men and 1.53 million DALYs in women, accounting for 41% of the global burden of osteoporosis.

The total DALYs were computed in the base case, in which years of life lost was weighted less in the elderly. When each year of life was valued at 1, the burden of DALYs increased from 5.8 million to 9.2 million (Table 7). As expected, changing assumptions concerning the excess mortality after hip fracture had a large impact on DALYs. When all deaths associated with hip fracture were assumed to be causally related, the numbers of DALYs lost doubled from 5.8 million to 11.3 million and increased still further to 18.8 million when the age weighting was removed.

The total burden of osteoporosis accounted for 0.83% of the global burden of noncommunicable diseases, though this varied markedly by region (Fig. 2). Figures 3 and 4 show the burden in Europe compared with that for other chronic diseases. Osteoporosis accounted for more DALYs lost than rheumatoid arthritis did, but less than for osteoarthritis. With regard to neoplastic disorders, the burden of osteoporosis was greater than for all sites of cancer, with the exception of lung cancers.

Table 5 Estimated prevalence of osteoporotic fractures (in thousands) in different regions of the world (*F/M* female-to-male ratio)

Region	Men	Women	Total	Percentage	F/M
Africa	205	207	412	0.7	1.0
Americas	2,621	6,375	8,999	16.0	2.4
Eastern Mediterranean	746	789	1,535	2.7	1.1
Europe	6,650	13,927	20,577	36.6	2.1
Southeast Asia	4,169	4,453	8,622	15.3	1.1
Western Pacific	7,067	9,003	16,069	28.6	1.3
World	21,457	34,755	56,212	100	1.6

Table 6 Estimated burden of disease expressed as disability-adjusted life-years (in thousands) by World Health Organization region using the base-case for mortality and age-weighting

Region	Men	Women	Total	Percentage
Africa	28	36	64	1.1
Americas	218	609	827	14.3
Eastern Mediterranean	77	100	177	3.0
Europe	655	1,351	2,006	34.6
Southeast Asia	446	606	1,051	18.1
Western Pacific	666	1,008	1,674	28.9
World	2,090	3,710	5,800	100

Table 7 Disability-adjusted life years (DALYs) lost (in thousands) in men and women with changes in assumptions on age weighting and excess mortality

Mortality assumption[a]	Age-weighted	Men	Women	Total
25%	Yes	2,090	3,710	5,800
25%	No	3,033	6,182	9,215
100%	Yes	4,183	7,130	11,313
100%	No	6,372	12,520	18,892

[a] Proportion of fracture-associated deaths

Discussion

This study is a first attempt to estimate the global burden of osteoporotic fractures in terms of their incidence, prevalence of disabled individuals, excess mortality, and DALYs. For the year 2000 we estimated approximately 9 million new osteoporotic fractures, of which 1.6 million were fractures at the hip, 1.7 million were fractures at the forearm, and 1.4 million were clinical vertebral fractures. Because some fractures incur disability for a period much longer than 1 year after the event, the number of individuals suffering the consequences of fracture is much larger than the annual incidence. Under the assumptions used for this study, this number was estimated at approximately 50 million worldwide. The annual number of hip fractures estimated in this study in the year 2000 compares with a previously published estimate for the year 1990 of 1.3 million hip fractures worldwide, representing an increase of approximately 25% [3]. The earlier estimate is somewhat lower than others for 1990 [1, 2], but the differences are relatively small and may be accounted for by the improved database on which to estimate hip fracture in different regions of the world. The present study also emphasises the importance of fractures other than hip fracture in contributing to the numbers of fractures. Indeed, hip fracture accounted for 18.2% of the total number of osteoporotic fractures. Because of the severe consequences of hip fracture in particular, a larger burden (40%) of the DALYs lost were accounted for by hip fracture. However, the majority of the global burden of osteoporosis is accounted for by fractures other than those at the hip (60%).

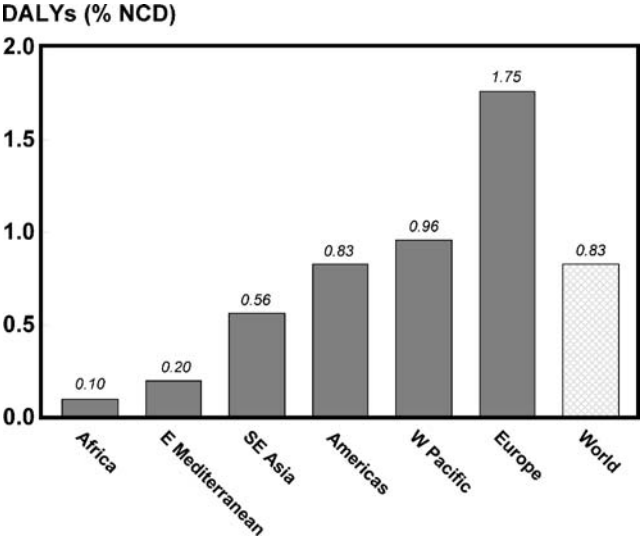

Fig. 2 Burden of osteoporosis in Europe expressed as the proportion of disability-adjusted life-years (DALYs) lost from osteoporotic fractures to the total DALYs lost from all noncommunicable diseases (NCD)

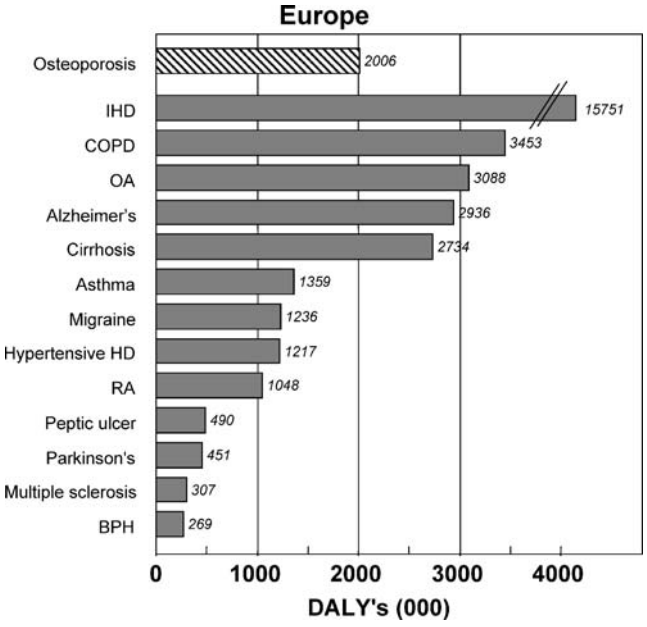

Fig. 3 Disability-adjusted life-years (DALYs) lost due to a selection of noncommunicable diseases in Europe (*IHD* ischaemic heart disease, *COPD* chronic obstructive pulmonary disease, *OA* osteoarthritis, *RA* rheumatoid arthritis, *BPH* benign prostatic hyperplasia)

An attractive feature of the approach used is that it permits comparisons across diseases. Overall, osteoporotic fractures accounted for 0.83% of the worldwide disability associated with noncommunicable diseases. For Europe, the proportion of noncommunicable diseases accounted for by osteoporosis was 1.75% of the total DALYs, and it outranked several other chronic diseases well established as burdensome to society, including rheumatoid arthritis and hypertensive heart disease. Our estimate suggests that osteoporotic fractures account for about two-thirds of the disability associated with osteoarthritis in Europe. Osteoporosis in Europe also contributed to a higher burden than the common neoplastic disorders, save only for lung cancer.

The present study is based on a large number of assumptions discussed previously [3, 22]. These include uncertainties about hip fracture rates in many subregions of the world. This deficit is, however, greatest for those regions of the world where hip fracture rates are assumed to be low, and more complete information is available for high

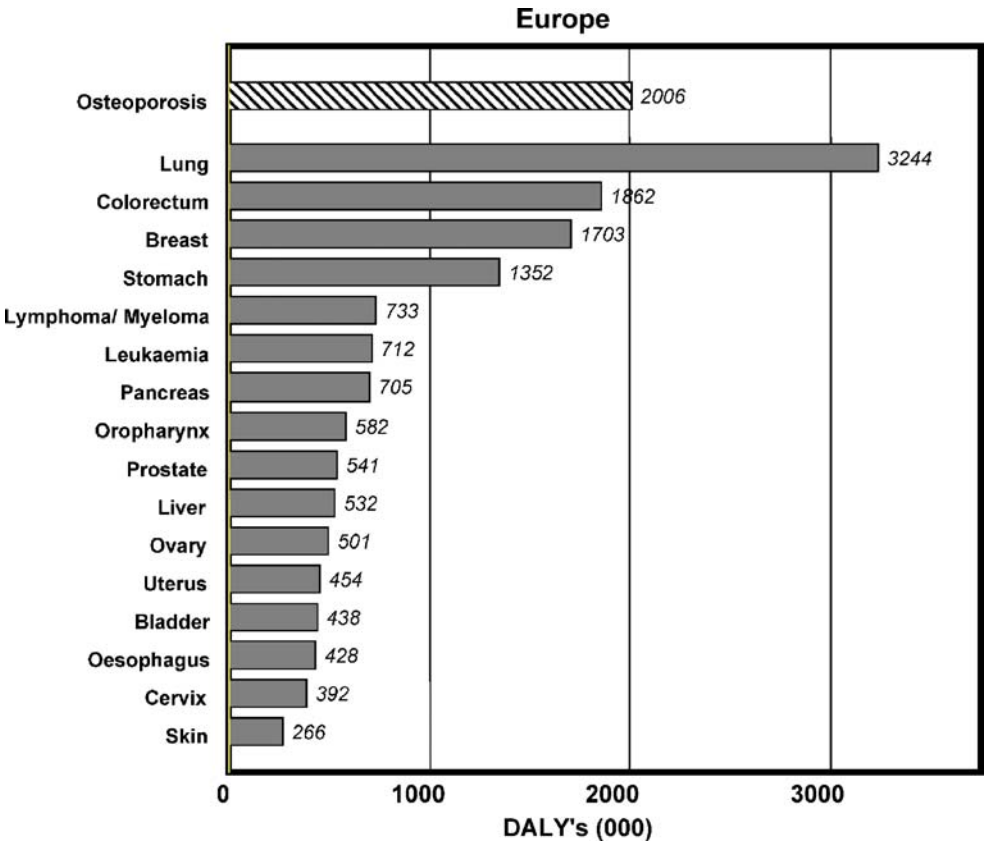

Fig. 4 Disability-adjusted life-years (DALYs) lost due to osteoporosis and to different neoplastic disorders in Europe

risk countries in the developed world. Also, data are lacking on the mortality due to fracture worldwide. In this study we assumed that the excess mortality was similar to that in Sweden. This may be a reasonable assumption for the developed countries, but in the underdeveloped countries it is possible that a lower standard of healthcare would result in much greater disability than we have estimated. Our estimates may, therefore, be somewhat conservative, but again, any additional morbidity in these countries has a relatively modest impact on the global burden because of the much lower number of osteoporotic fractures. The data on disability associated with osteoporotic fractures are also largely drawn from Sweden. Although similar estimates are available from the UK, particularly for hip fracture [23], almost no data are available for the international variation in disutility associated not only with hip fracture but also for the many other types of osteoporotic fracture. Because of the uncertainties of disutility values several years after major fractures such as hip and pelvic fractures, we discounted utilities from the second year by 10% per year, and this high discount might also underestimate the long-term disability. All of these limitations point to the need for more epidemiological information on fracture rates and their implications worldwide.

Over and above these limitations, the age- and gender-adjusted burden of osteoporotic fractures other than hip fracture has been imputed from the ratio of hip fracture to other osteoporotic fractures using a Swedish database. For long bone fractures, this assumption seems to be reasonable, at least in the Western world (see Methods), but it may not hold true for vertebral fractures [24, 25]. There is a high correlation between hip fracture rates and admission to hospital for vertebral fracture such that vertebral fracture discharges are high in those regions where the incidence of hip fracture is also high [26, 27]. By contrast, prospective studies of the incidence of morphometric vertebral fractures have shown much less heterogeneity in vertebral fracture risk around the world [24, 25, 27]. If the disability associated with these fractures was shown to be similar worldwide, this would have a marked impact on increasing the disability associated with all osteoporotic fractures.

Most of these assumptions are conservative. With these caveats, the present data suggest that osteoporotic fractures comprise a very significant disease burden to society, particularly in the developed countries.

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