

## Requirements for DXA for the management of osteoporosis in Europe

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**Abstract** The availability of dual energy X-ray absorptiometry (DXA) varies markedly in different countries. There is, however, little information to indicate the optimal requirements for this technology. The principal aim of this study was to estimate the requirements for DXA in Europe for the assessment and treatment of osteoporosis. Three assessment scenarios were chosen. The first envisaged screening of all women with DXA at the age of 65 years. A second scenario comprised a screening programme based on the identification of clinical risk factors with the selective addition of BMD tests in those close to an intervention threshold. The third scenario envisaged a case finding strategy where women aged 65 years were identified on the basis of risk factors and referred for DXA. Requirements for women aged more than 65 years were amortised over a 10-year period. A secondary aim was to estimate the number and cost of osteoporotic fractures in Europe. The requirements for DXA in assessment ranged from 4.21 to 11.21 units/million of the population. The most efficient assessment scenario was the use of clinical risk factors with the selective use of BMD. With this scenario, an additional 6.39 units/million would be required to monitor treatment giving a total requirement of 10.6 units/million. In 2000, the number of osteoporotic fractures was estimated at 3.79 million, of which 0.89 million were hip fractures (179,000 hip fractures in men and 711,000 in women). The total direct costs were

estimated at €31.7 billion (£21.165 billion), which were expected to increase to €76.7 billion (£51.1 billion) in 2050 based on the expected changes in the demography of Europe.

**Keywords** Dual energy X-ray absorptiometry · Europe · Fracture probability · Hip fracture · Osteoporotic fracture · Risk assessment · Screening

### Introduction

The clinical significance of osteoporosis lies in the fractures that occur. Many fracture types are associated with osteoporosis, but the hip, spine, forearm and shoulder are the most common sites. The probability of sustaining osteoporotic fractures varies markedly in different regions of the world. In Europe, the highest risks of hip fracture are seen in Norway, Sweden, Iceland and Denmark, whereas Germany, Switzerland, Finland, Greece, The Netherlands, Hungary, Italy, the UK and Portugal have been described as “high risk” countries defined as having a hip fracture probability that lies between 50% and 75% of the risk that is observed in Sweden [1].

Within Europe, the cost and consequences of osteoporosis have been well characterised, particularly in Northern Europe [2]. In Sweden, the probability of sustaining an osteoporotic hip fracture in women at the age of 50 years is 22.9% in their remaining lifetime [3]. The equivalent figure for men is 10.7%. The risk of sustaining a clinical vertebral fracture at the age of 50 years is 15.1% in women and 8.3% in men. For any common osteoporotic fracture (i.e. hip, spine, shoulder, forearm), the remaining lifetime risk at the age of 50 years is 46.4% in women and 22.4% in men. This places a significant burden on the hospital system and hip fractures, for example, account for 63% and 72% of hospital admissions for fracture in men and women over the age of 50 years [4]. In 1996, hip fractures in Sweden

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accounted for nearly as many hospital days as acute myocardial infarction (0.3 versus 0.4 million, respectively) and for more than prostate cancer and breast cancer combined (0.1 million) [4].

Against this background, many new treatments for osteoporosis have been developed in recent years, that can significantly decrease the risk of vertebral fracture and in some cases of non-vertebral fracture including hip fracture [5]. Despite the availability of effective treatments, many individuals with established osteoporosis and many more with osteoporosis and at high risk are not treated [6–10]. Part of the problem relates to the lack of general awareness that a prior fracture is a strong risk factor for further fractures. A further reason relates to heterogeneity in the access for bone mineral density (BMD) measurements and their reimbursement in different countries.

The aim of the present study was to estimate current needs for densitometry in the assessment and management of patients in Europe. Since this requires knowledge of the population demography of Europe and of fracture probability, a further aim was to estimate the number and direct costs of osteoporotic fractures in Europe today and over the next 50 years.

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## Materials and methods

There is a wide variety of technologies available for the assessment of osteoporosis. For diagnosis, there is a general view that the proximal femur assessed by DXA should be used as the reference standard [11]. In contrast, many other sites and technologies can be usefully used for the assessment of fracture risk, though it should be recognised that the performance characteristics differ. For the purposes of this study, DXA at the hip was chosen as the reference technology, since this provides diagnostic information, predicts hip fracture with greatest accuracy, and predicts the risk of any fracture as well as other validated techniques applied to other sites. For monitoring of treatment, it was assumed that DXA at the lumbar spine would be used, since this is the site that appears to be most responsive to intervention.

### Case finding strategies

Several approaches were taken to assess requirements for DXA. The first (scenario A) was to examine the impact of a screening strategy targeted to women at the age of 65 years assuming 100% compliance. This age was chosen since screening of women at this age is advocated in the US [12,13] and health economic analyses in the US and in Europe suggest that a meaningful proportion of women at this age have a fracture risk above a threshold at which intervention becomes cost-effective [12,14]. In addition to screening women at the age of 65 years, account was taken of the requirements

for those aged 66 years or more amortised over a 10-year interval.

A second approach (scenario B) was to assume that a screening policy would be instituted based on the elicitation of clinical risk factors every 10 years in women from the age of 65 years. BMD tests would be offered in those close to a threshold risk [15]. A previous estimate in a population of women aged 75 years or more suggests that approximately 21% of the female population would require a BMD test for the accurate characterisation of fracture risk [15].

The general approach was validated in additional population-based cohorts [16]. Significant independent risk factors were used to characterise hip fracture probability by the use of Poisson models applied to seven prospectively studied population-based cohorts from Europe. These comprised the European Prospective Osteoporosis Study, the Sheffield Cohort, the Rotterdam Study, OFELY, Kuopio and two cohorts from Gothenburg [16]. A total of 12,027 men and 33,157 women aged 50 years or more were studied. Approximately 250,000 patient years of follow-up were available, during which time there were approximately 1100 hip fractures. The clinical risk factors included age, BMI (higher or lower than 25 kg/m<sup>2</sup>), previous fragility fracture, a maternal history of any fragility fracture, smoking (ever versus never), long-term use of corticosteroids and secondary causes of osteoporosis.

The 10-year probability of hip fracture was computed from the use of clinical risk factors. A threshold risk was set according to intervention thresholds determined for the population of Swedish women [17]. At the age of 65 years a 10-year hip fracture probability of 4% provided an intervention threshold.

In women with a probability of 3.5% or less on the basis of clinical risk factors, BMD tests would not be additionally undertaken since the probability of a false negative result is low ( $P_1$  set at 0.2). Conversely individuals with a hip fracture probability of > 5.5% would not need a BMD test (for risk assessment), since their probability of being a false positive was low ( $P_2$  set at 0.8). In this example, 66.8% of women would not need a BMD test because their 10-year probability was 3.5% or less. Additionally, 9.4% of women would not need a BMD test because their 10-year fracture probability was greater than 5.5%. Thus, 23.8% of women would require a BMD test comprising 14% that would not require treatment (fracture probability < 4%) and 9.8% that would require treatment (fracture probability > 4%).

A third scenario (scenario C) was to examine the implications of a case finding strategy that is currently applied in several European countries and supported by the EU [2,18–20]. This envisages the referral of women with strong risk factors for fracture for densitometry. The approach requires information on the prevalence of risk factors in the community. For this purpose we examined the prevalence of the internationally validated clinical risk factors in the eight population-based cohort studies from Europe described previously. The

risk factors examined were low body mass index ( $< 19 \text{ kg/m}^2$ ), prior fragility fracture, current or ever long-term use of corticosteroids, parental history of hip fracture, secondary causes of osteoporosis (eg rheumatoid arthritis), excessive alcohol use ( $> 2$  units daily) and current smoking.

### Requirements of DXA for treatment

The risk factors detailed above were applied to the cohorts to determine the distribution of the 10-year probability of hip fracture (as detailed for scenario B). An intervention threshold was set as mentioned at a 4% 10-year hip fracture probability which corresponded to a threshold for women aged 65 years based on a cost-utility analysis in Sweden [17]. In this scenario, a proportion of individuals characterised at high risk, would not have had a BMD test for the purposes of case-finding (9.4% of the population aged 65 years). In these patients, it was assumed that they would require a BMD test at the start of treatment. Repeat BMD tests would be undertaken at 2 years in these patients, as well as in those patients identified at high risk on the basis of the screening BMD test.

It was additionally assumed that individuals over the age of 65 years would be tested over the ensuing 10 years.

### Current utilisation of DXA

A survey was undertaken of the Committee of Scientific Advisors of the International Osteoporosis Foundation to determine the service utilisation for DXA. Twenty-three centres responded, giving details of the service throughput. On average, 3000 patients were screened annually per centre with a staffing requirement of 2.39 full-time equivalents to service this need. On average, 1256 patients were scanned for each DXA unit per year, usually (91%) at both the lumbar spine and proximal femur, and provided the assumptions used.

### Demography

Population demography was obtained using data from the UN [21] for the year 2000. The same source was used for the expected changes in the population with calendar year up to 2050. For the purpose of computing costs and incidence of fractures, demography was assessed separately for Eastern, Northern, Southern and Western Europe, as defined by the UN. *Eastern Europe* comprised Belarus, Bulgaria, Czech Republic, Hungary\*, Poland, Moldova, Romania, The Russian Federation, Slovakia and the Ukraine. *Northern Europe* comprised the Channel Islands, Denmark\*, Estonia, Faroe Islands, Finland\*, Iceland\*, Ireland, Isle of Man, Latvia, Lithuania, Norway\*, Sweden\*, UK\*. *Southern Europe* comprised Albania, Andorra, Bosnia and Herzegovina,

Croatia, Gibraltar, Greece\*, the Holy Sea, Italy\*, Malta, Portugal\*, San Marino, Serbia and Montenegro, Slovenia, Spain\* and the former Yugoslav Republic of Macedonia. *Western Europe* comprised Austria, Belgium, France\*, Germany, Lichtenstein, Luxembourg, Monaco, Netherlands\* and Switzerland\*.

### Incidence of hip fracture

The incidence of hip fracture was taken from publications since 1990 reported in Kanis et al. [1] in 5-year intervals in men and women from the age of 50 years. Countries available were those marked with an asterisk above. In several countries (Finland, Sweden, UK, France, Switzerland, Greece, Italy, Portugal and Spain) more than one estimate was available, and mean values were computed for each country. For each region of Europe we took the mean estimate from countries in each region. Estimates were not weighted for population size, since each region, with the exception of Northern Europe, was represented by a minority of countries.

### Other osteoporotic fractures

The definition of osteoporotic fractures other than hip fracture is imperfect. Fractures have been variously characterised as those associated with low energy trauma, those occurring at sites associated with low bone mineral density, and those occurring at sites associated with a high risk of subsequent fracture. For the purpose of this report, we defined osteoporotic fractures as those associated with low bone mineral density [22], the incidence of which increases with age after the age of 50 years [23]. The following fracture sites were considered to be due to osteoporosis in women: spine fractures excluding cervical fractures and those associated with neoplasia, rib, pelvis, humerus, forearm, hip and other femoral fracture, tibia and fibula, clavicle, scapula and sternum. In men, tibial fractures were not regarded as osteoporotic, but the sites chosen were otherwise the same.

The incidence of fractures other than hip fracture was computed in 5-year age intervals in men and women from the ratio of the incidences of each site to hip fracture incidence in Sweden [23]. This assumes that for each sex and at each age interval, the ratios are similar in different geographic regions. The available evidence is scanty, but consistent with this assumption, at least in the case of non-vertebral fracture risk [23–27]. For vertebral fracture, there is some evidence that the heterogeneity of incidence in morphometric vertebral fractures in different European countries is substantially less than that for hip fracture [2,28,29]. There is, however, a close correlation between clinical vertebral fracture and hip fracture discharge rates from hospital [30].

## Costs

For hip fracture costs, we used estimates from the UK derived from Dolan and Torgerson [31]. Direct cost estimates were constructed for patients discharged home (45% of cases), patients discharged to long-term residential care (25%), and patients dying within the first year of hip fracture (30%). Costs were age-weighted [32]. Aggregate costs of hip fracture (1999/2000 prices) were £13,519 in the first year and £5291 in the second year, giving a total cost £18,810 per hip fracture. Costs of vertebral fracture were estimated at £771 but age weighted using the same sources of information. Costs in £ were converted to Euros (£1 = €1.498; 26 May, 2004).

For osteoporotic fractures other than vertebral and hip fracture, costs were assumed to be proportional to their disutility [23]. The assumption appears to hold true, at least in the United Kingdom and the United States [31,33]. In the study from the US [33], the total incremental costs of all osteoporotic fracture other than those at the hip were 47% and 46% higher than the costs of hip fracture in men and women, respectively. The morbidity of non-hip osteoporotic fractures was 39% and 47% higher than for hip fracture in men and women, respectively. Between the ages of 80 and 84 years the costs of all osteoporotic fractures were assumed to be 50% greater than the costs of hip fracture in men and 55% greater in women. For vertebral fractures, costs

were assumed to be 27% of the cost of hip fractures in men and 26% in women.

## Results

The numbers of men and women in Europe is summarised by age and sex in Table 1. The total population was estimated at nearly 728 million of whom just over 4 million were women aged 65 years.

### Requirements of DXA for risk assessment

The first scenario (scenario A) envisaged screening all women with DXA at the age of 65 years. The target population comprises 4,045,000 women at the age of 65 years. If a screening policy were to identify and measure BMD at the age of 65 years in all women at this age, this would require 3231 DXA units or a requirement of 4.42 DXA units per million of the total population. This ignores the unscreened population aged 66 years or more. When these are included and screened over a 10-year period, the requirements for DXA units would be 6.79/million of the total population, giving a total requirement of 11.2 units/million (Table 2).

The second scenario (scenario B) envisaged screening women at 10-yearly intervals by clinical risk factors of whom a proportion of women would be referred for DXA. From the distribution of hip fracture risk determined by the use of clinical risk factors at the age of 65 years, and an intervention threshold set at a 10-year hip fracture probability of 4%, screening all women at the age of 65 years would require 767 DXA units or 1.05 scans/million of the population.

Intervention thresholds expressed as hip fracture probability differ by age, and an increasing proportion of the population are selected for treatment with advancing age. The proportion ranges from approximately 1% at the age of 50 years to 52% at the age of 80 years. By contrast, the absolute population size decreases the higher the starting age for testing. Using these assumptions, a policy that assessed women over the age of 65 years over 10 years would require an additional requirement of 2301 DXA units or 3.16/million of the population, with a total requirement of 4.21/million (see Table 2).

**Table 1** Population size (000) of Europe, 2002

Age	M + F	M	F
50–54	45,871	22,346	23,526
55–59	36,939	17,640	19,299
60–64	40,230	18,415	21,815
65–69	33,325	14,702	18,623
70–74	30,662	12,370	18,292
75–79	21,944	7755	14,189
80–84	10,747	3446	7301
85–89	7356	2027	5329
90–94	2598	620	1977
95–99	501	103	398
100+	46	9	37
0–49 years	497,767	251,467	246,300
50+ years	230,219	99,433	130,786
65+	107,179	41,032	66,146
80+	21,248	6205	15,042

**Table 2** Requirements for DXA units for assessment of women using three different scenarios and the requirements to monitor treatment in women at the age of 65 years and in women above this target age amortised over 10 years

Scenario	Age 65 years		Age > 65 years		Total	
	Units	Units/million	Units	Units/million	Units	Units/million
A. Screening women with BMD	3321	4.42	4944	6.79	8165	11.21
B. Clinical case finding with selective use of BMD	767	1.05	2301	3.16	3068	4.21
C. Classic case finding strategy	1481	2.03	2423	3.33	3904	5.36
D. Monitoring treatment	966	1.33	3686	5.06	4652	6.39

Because a smaller proportion of the population is selected for BMD tests at younger ages, the requirements are not markedly altered by a policy that starts at the age of 50 years. At this age, approximately 1% of women are selected for treatment. Of approximately 5 million women aged 50 years, DXA tests would be required in 50,000, giving a requirement of 40 scanning units or 0.05 units/million of the total population. To this must be added screening of the population aged more than 50 years over a 10-year term interval. This requires a provision of 3249 units or 4.46 units/million. Thus, the total requirement is 4.5/million. This compares with a total requirement of 4.21/million when testing is started at the age of 65 years.

The third scenario was to identify women with strong risk factors for fracture and refer these for densitometry. The prevalence of these risk factors (Table 3) varied from approximately 29% to 46% depending on age. BMD tests at the age of 65 years would require 1481 units or 2.03 units/million of the population. If BMD tests were to be undertaken in women aged more than 65 years with these risk factors at a prevalence of 46%, then approximately 30 million women would require testing, or 3 million per year amortised over a 10-year interval, or a requirement of 2423 scanners in Europe. This is equivalent to 3.33 units/million of the population (see Table 2).

If BMD tests were to be undertaken in women aged 50 years or more with one or more these risk factors, this would require BMD testing in 36.9% of the female population aged 50 years or more. This would require 3842 scanning units or 5.3/million of the general population. The referral for BMD of only women aged 65 years or older with an incident osteoporotic fracture gives a requirement of 918 scanning visits or 1.3/million of the general population.

#### Requirements of DXA to monitor treatment

Two BMD tests are envisaged in women committed to treatment. One is at the time of assessment, and a second at an interval of 2 years. For scenario B, BMD tests would have been undertaken in 24% of the population at the age of 65 years, some of whom would fall above an intervention threshold and not require a further BMD test at the start of treatment. Additional BMD testing would be required in approximately 10% of women for the purposes of baseline assessment for

treatment. If all 65-year-olds were screened, additional pre-treatment BMD tests would amount to 0.4 million scans (322 units) and approximately double the number 2 years later. Thus, the steady state requirements would be 966 scanners or 1.33 units/million of the population.

In women older than 65 years, the population is smaller, but a larger proportion would exceed an intervention threshold. For example, at the age of 80 years there are approximately 2.15 million women, but with the same test 73% would be identified for treatment. At the age of 50 years, approximately 1% of 5 million women would be identified for treatment.

In women aged 65 years or more approximately 35% are identified for treatment and require a BMD test before treatment and 2 years later. This gives an annual requirement for 4.6 million scans or 3686 scanning units and a requirement of 5.06/million of the general population (see Table 2). Thus, the total requirement for the monitoring of treatment is 6.39/million under assessment scenario B. The total for assessment plus monitoring of treatment is therefore 10.6 scanning units/million of the population.

#### Osteoporotic fractures

The number of osteoporotic fractures estimated in Europe for the year 2000 is shown in Table 4. In men this was estimated at 1,053,172, of which 178,777 were hip fractures and 163,151 were clinical spine fractures. Amongst women there were 2,739,863 fractures of which 711,223 were at the hip and 406,493 at the spine.

A summary of costs is shown in Table 5. The combined costs in men and women for osteoporotic fractures were €36,248 million, of which €24,353 million were for hip fracture, €719 million for vertebral fracture and €11,177 million for other osteoporotic fracture. Costs were approximately 3-fold higher in women than in men.

The size of the population aged 50 years or more is predicted to increase by 36% in men and 26% in women by 2050 (Table 6). The increment is most marked in the elderly, and in the population aged 65 years or more, the percentage increase expected by 2050 is 239% and 160% in men and women, respectively. Since fractures, particularly hip fractures, rise exponentially with age and the costs of fracture rise with age, there is a disproportionate effect on costs (Table 7). Costs in men are expected to rise from €8.7 billion in 2000 to €22.8 billion in 2050, a 2.6-fold increase. In women, the costs approxi-

**Table 3** Prevalence (%) of risk factors for fracture in European women

Age range (years)	Low BMI	Current smoking	Prior fracture	Corticosteroids	Parental history of hip fracture	Secondary osteoporosis	Alcohol > 2 units	Any risk factor
50–59	1.3	16.2	17.8	4.5	5.1	–	16.1	33.7
60–69	1.5	18.4	25.8	4.5	6.4	–	14.1	45.7
70–79	2.1	10.4	31.7	5.8	7.1	2.4	10.0	43.3
80–89	4.0	4.7	31.3	4.6	4.9	2.2	7.2	38.5
90+	0.8	3.7	22.0	2.2	6.9	7.9	0.0	28.5

**Table 4** Number of fractures in Europe in men and women at the sites shown in the year 2000

Age (years)	Men				Women			
	Hip	Spine	Other	Total	Hip	Spine	Other	Total
50–54	6033	27,993	94,115	128,221	7764	30,513	163,820	202,097
55–59	9349	11,111	153,324	173,784	13,316	23,037	145,810	182,163
60–64	16,205	27,224	88,965	132,394	26,178	43,717	158,900	228,795
65–69	19,701	17,337	106,582	143,620	42,460	47,980	198,288	288,728
70–74	31,420	31,734	95,831	158,538	84,175	79,966	183,502	347,643
75–79	31,253	20,627	47,505	99,385	115,782	75,258	248,931	439,971
80–84	26,190	12,833	62,332	101,355	104,258	36,490	199,133	439,881
85+	38,626	14,292	62,960	115,878	217,290	69,533	323,762	610,585
50+	178,777	163,151	711,636	1,053,172	711,223	406,493	1,622,146	2,739,863

**Table 5** Estimated costs of osteoporotic fractures in Europe (€000) by fracture site, age and sex

Age range (years)	Hip	Spine	Other	Total
<i>Men</i>				
50–64	544	69	473	1086
65–74	1111	63	389	1563
75–84	1637	45	360	2042
85+	1264	21	2781	4067
50+	4556	198	4003	8757
<i>Women</i>				
50–64	813	101	1253	2168
65–74	2751	165	1376	4293
75–84	9120	152	2553	11,824
85+	7112	102	1992	9206
50+	19,796	521	7173	27,491
<i>Men and women</i>				
50–64	1358	171	1725	3254
65–74	3863	230	1764	5856
75–84	10,757	197	2915	13,868
85+	8376	123	4773	13,272
50+	24,353	719	11,177	36,248

**Table 7** Projected costs of osteoporotic fractures in Europe (€000,000)

Calendar year	Men	Women	Men and women
2000	8.7	27.5	36.3
2005	9.2	29.6	38.7
2010	10.5	32.0	42.6
2015	12.2	35.1	47.3
2020	13.2	36.3	49.7
2025	14.7	39.3	54.0
2030	15.8	42.2	57.9
2035	17.7	46.1	63.8
2040	19.7	49.7	69.3
2045	21.3	52.2	73.5
2050	22.8	53.9	76.8

mately double from €27/5 billion in 2000 to €53.9 billion in 2050.

## Discussion

The present study provides an approximation of the requirements for DXA in Europe, and the current burden and costs of osteoporotic fractures. They are

approximations, since a large number of assumptions are made, but the assumptions are transparent both for fracture burden and for the requirements of DXA, so that further estimates using different assumptions or empirical data could be applied.

## Fractures

Data on hip fracture incidence are scarce with the exception of Northern Europe. Indeed, of the 48 countries represented within the UN boundaries of Europe, hip fracture incidence is available only in 13 countries, six of which are found in Northern Europe. Only one country was available from Eastern Europe (Hungary), and there is clear need for further information. The

**Table 6** Percent increase expected in the male and female population according to age category. The population (000) in 2000 is shown in parentheses

	Men 50+ (99,433)	Women 50+ (130,786)	Men 65+ (41,032)	Women 65+ (66,146)	Men 80+ (6205)	Women 80+ (15,042)
2000	0	0	0	0	0	0
2010	15	12	12	8	49	38
2020	29	22	34	23	85	61
2030	37	28	60	42	122	81
2040	42	31	75	52	187	130
2050	36	26	81	55	239	160

incidence of spine and other osteoporotic fractures is the even less well characterised. For this reason, we assumed that the risks of these osteoporotic fractures were proportional to the incidence of hip fracture, using Sweden as the reference country. Whereas the assumption appears to be reasonable in the case of appendicular fractures [23], there is some uncertainty concerning spine fractures. There is a close correlation between discharge rates for spine and hip fracture [30], but there is also a close correlation between hip fracture risk and the ability to pay for hospital care, as judged by gross domestic product per capita [34]. Thus, the correlation may reflect higher hospital admission rates for vertebral fractures in those countries with higher economic prosperity.

When vertebral fractures are assessed by vertebral morphometry, the heterogeneity and incidence within Europe appears to be markedly lower than that for hip fracture or hospital admission for vertebral fracture [28]. In the case of hip fracture, there is an 11-fold range in standardised incidence of hip fracture amongst women in Europe [35]. In contrast, morphometric deformities vary only by 3-fold [28,36], ranging from 7.6% in Bochum, Germany to 20.7% in Malmö, Sweden in women over the age of 50 years. The proportion of morphometric fractures that come to clinical attention is approximately 23% in Sweden and the United States [37,38]. It is not known, however, whether the ratio would also pertain to other countries.

A further assumption concerns the costs of fractures. For the purpose of this study we have assumed costs referable to the UK. This was chosen in preference to Sweden where costs have also been well characterised, but are higher than those in the UK. Values for the UK are thus likely to lie closer to the mean value for Europe. The hip fracture costs in the present study are consistent with those estimated previously for the European Union [2]. The costs of vertebral fracture are also consistent with those reported for the EU [39].

For the purposes of this report, we have assumed that the costs of fractures other than hip or vertebral fractures were proportional to the societal burden (incidence adjusted by disutility). The assumption is consistent with comparative costings in the USA [33] and in the UK [31], but may not necessarily apply to other countries.

An important assumption concerning future costs and frequency of fractures relates to demographic changes expected up to the year 2050. The projected increase in the elderly population is, however, reasonably secure since those individuals who will be over the age of 50 years in the year 2050 have already been born. The future burden may, however, be conservative, since in many countries the age and sex specific incidence of fractures, best documented for hip fracture, is increasing [40]. Indeed, the number of fractures estimated for 2050 may be double those that we have shown, even using relatively conservative assumptions for the secular trend [40].

## Requirement for DXA

The estimated requirements for DXA are methodologically more sound than that for fracture burden and costs, in the sense that they are largely based on the population demography. The major uncertainty relates more to the impact of the scenarios modelled. For the three assessment scenarios, we have assumed 100% uptake, which is highly improbable in any country. Rather the data provided should be taken as providing estimates of the maximal requirements for each scenario. Uptake will vary according to the healthcare setting, particularly reimbursement for DXA, and healthcare priorities, since the capital costs of DXA are similar throughout Europe.

Not surprisingly, the requirement for DXA is greatest for the scenario of widespread population screening where in excess of 8000 densitometers or 11.2 units per million of the general population would be required. This contrasts with the classic case finding strategy that is currently practised in many European countries and has a DXA requirement of 5.36 per million of the population. In Sheffield, where opportunistic case finding has been practised for more than 10 years, referrals for DXA are appropriate in the sense that they follow the guidelines of the Royal College of Physicians [41]. The service provision for the catchment area amounts to approximately 4.0 DXA units per million of the population (E McCloskey, 2004, personal communication). Assuming that half these tests are for the monitoring of treatment rather than for the first time assessment, this might suggest an uptake rate of somewhat less than 40%.

The least requirement for DXA was the use of clinical risk factors and the subsequent selective use of BMD, since not all individuals with risk factors require an estimate of BMD. At the age of 65 years, 23.8% of women would require a DXA scan, which is considerably lower than the prevalence of major risk factors (see Table 3). Under this scenario, 19.2% of women aged 65 years would have a fracture probability that exceeded an intervention threshold at least for Sweden. It should be noted that fracture probabilities are high in Sweden compared to many other European countries, and there is a great deal of heterogeneity in fracture probability within Europe [1,29,35], as well as in the costs of fracture and costs of intervention. For countries with low hip fracture rates, as found in Eastern Europe, the relative risk at which intervention is cost effective will be higher, though the absolute risk at which intervention is cost effective would not change assuming comparable costs. Thus, in countries with fracture rates lower than the UK, a lower proportion of the population would be identified for treatment. Intervention thresholds would, however, change with differences in cost, particularly fracture costs, which in most countries are poorly documented. A further important variable in other healthcare settings is willingness to pay for treatment. The gross domestic product (GDP) varies markedly in different regions of the world. In the UK, the GDP per

capita is estimated at \$25,300 in 2002, but is only \$13,300 in Hungary. Thus, for the same fracture risk and the same costs, treatment will be less affordable (at least to health services) in Hungary than in the UK. These factors are also likely to decrease the proportion of the population identified for treatment.

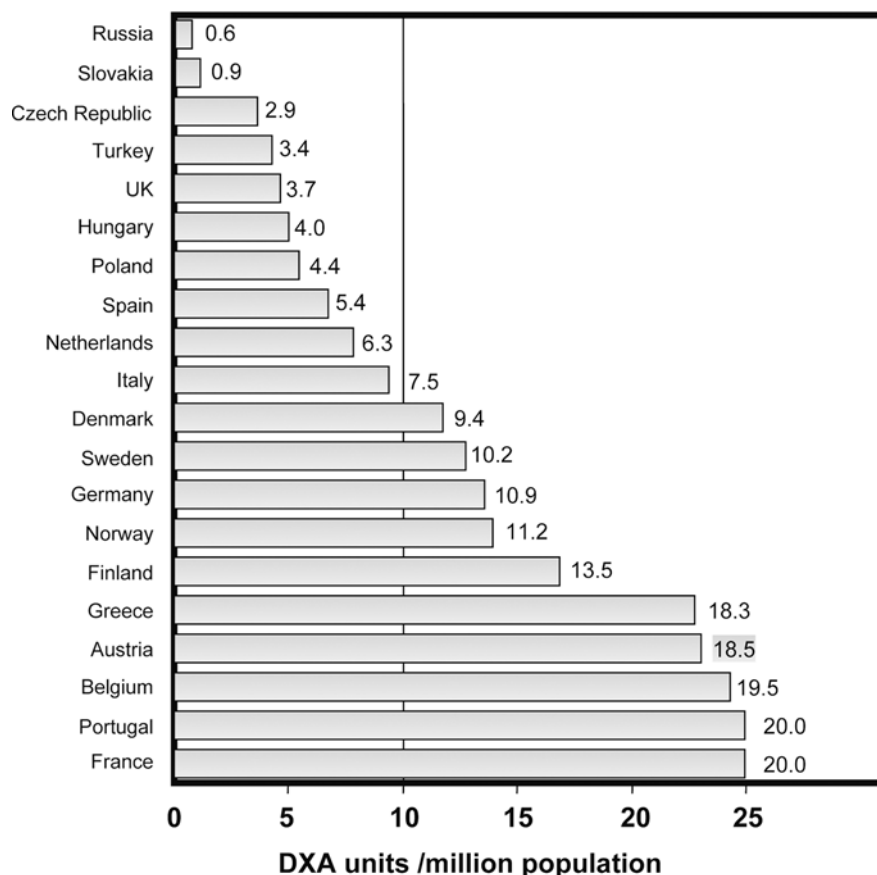
We have based our assumptions concerning the requirements for DXA to monitor treatment on the assessment scenario using clinical risk factors and selective use of BMD. There is, however, great uncertainty concerning the way in which treatments should be monitored, and the role, if any, of BMD measurements [42]. The problem arises because of the relatively small treatment-induced changes in BMD compared to the precision errors of the measurement. For this reason, we conservatively assumed the baseline BMD and only one further test 2 years later. Notwithstanding, the long-term requirement for the monitoring of treatment amounted to 6.39 DXA units per million of the population compared with a requirement of 4.21 scanners per million for the case finding strategy. Thus, the monitoring consequences of treatment are greater than that for the case finding. It thus becomes important to develop internationally agreed guidance on the use of DXA for the monitoring of treatment.

The combined estimate for assessment and monitoring amount to 10.6 DXA units per million of the general population which is similar to a previous estimate [43].

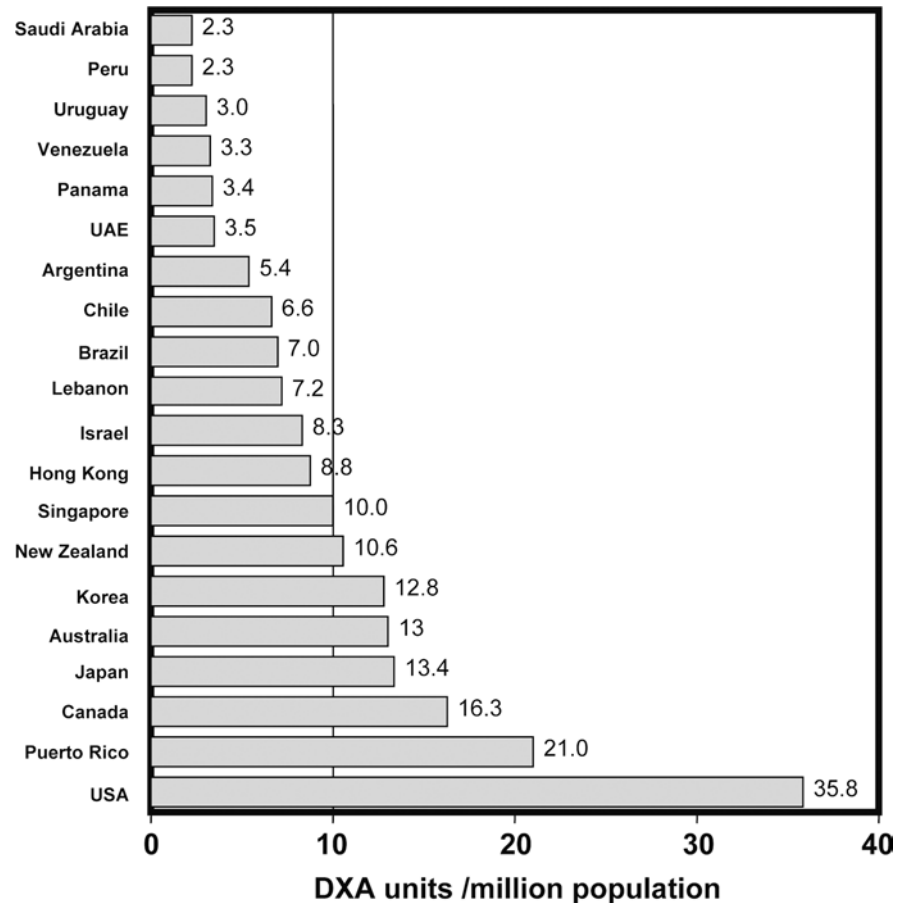
This requirement can be compared with the current availability of DXA in different European countries (Fig. 1). Of the 20 countries where information is shown, nine countries have more than 10 DXA units per million of the population. It is important to note that the figure provided does not distinguish machines dedicated in part or in full to clinical research, or machines that lie idle or are underutilised because of lack of funding. It is likely, therefore, that the majority of countries are under-resourced. A further consideration is the inequity of geographical location, which is known to be problematic in Italy, Spain, Switzerland and the UK. The most extreme example is found in India, where there are approximately 100 DXA units, but these are located in six cities. This inequity results in long waiting times or long distances to travel or in many cases no access. In other regions of the world, only eight countries have more than 10 units per million of the general population (Fig. 2).

The interest in the combined use of risk factors with bone mineral density is that the gradient of risk per standard deviation change in risk score is higher than with the use of BMD alone. The effect of this is to improve the detection rate of individuals who will fracture (sensitivity), without sacrificing specificity. The combined use of risk factors together with BMD provides a gradient of risk of approximately 3 per standard deviation, and this permits the impact of

**Fig. 1** Density (number/million population) of central DXA (spine/hip) units in different European countries in 2003



**Fig. 2** Density (number / million of the population) of central DXA (spine/hip) units in non-European countries in 2003. Data not shown for the following countries with DXA units <2.0/million. Columbia, Ecuador, Mexico, Malaysia, Tunisia, South Africa, Guatemala, Thailand, Philippines, China, India and Indonesia



such a strategy to be computed. In women at the age of 65 years the intervention threshold we have modelled is a 4% 10-year hip fracture probability. This compares with a probability of 2% in the general female population aged 65 years, i.e. a relative risk of 2.0. The case finding strategy would identify 11.9% of the population with an average relative risk of 3.93 [44]. Thus, the population selected would have a 10-year hip fracture probability of 7.86% ( $3.93 \times 2.0$ ). In Europe with approximately 40 million women at the age of 65, a total of 81,000 hip fractures would be expected over 10 years. In the proportion of individuals selected for treatment (11.9%) approximately 38,000 hip fractures would be expected over 10 years. If 50% of these fractures are saved by treatment then the overall impact would be a saving of 19,000 hip fractures out of 81,000 in 65 year old women, a saving of approximately 23%.

We conclude that the provision of DXA in Europe, and indeed globally is likely to be sub-optimal. The most effective use of resources for assessment is the use of clinical risk factors with the selective use of BMD. Since much of the requirements for DXA relates to the monitoring of treatment, clear guidance on the optimal use of DXA for monitoring is required. The current burden of osteoporotic fractures is enormous, in excess of €30 billion in the year 2000. This is expected to more than

double to €76.7 billion in the year 2050, assuming conservatively no increase in age and sex specific incidence of fractures. The efficient use of BMD for assessment could save up to a quarter of all fractures.

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