Geographic and ethnic disparities in osteoporotic fractures

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Abstract | Osteoporotic fractures are a major worldwide epidemic. Here, we review global variability, ethnic differences and secular changes in osteoporotic fractures. Worldwide, age-standardized incidence rates of hip fracture vary >200-fold in women and >140-fold in men when comparing the country in which incidence rates are the highest with that in which they are the lowest. Median age-standardized rates are highest in North America and Europe, followed by Asia, Middle East, Oceania, Latin America and Africa. Globally, rates of hip fracture are greater in women than in men, with an average ratio of ~2:1. The incidence of radiographic vertebral fractures is much higher than that of hip fractures, whereas the incidence rates of clinical vertebral fractures mirror hip fracture rates in most countries. Methodological challenges of defining and ascertaining vertebral fractures limit the interpretation of these data. Secular declines in hip fracture rates have been reported in populations from North America, Europe and Oceania. These declines are especially notable in women, suggesting that reproductive factors might contribute to this reduction. By contrast, hip fracture rates are increasing in parts of Asia and Latin America. Global indicators of health, education and socioeconomic status are positively correlated with fracture rates suggesting that lifestyles in developed countries might contribute to hip fracture. Improvements in fracture assessment, in particular for nonhip fractures, and identification of factors that contribute to this variability might substantially influence our understanding of osteoporotic fracture aetiology and provide new avenues for prevention.

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Introduction

The average age of the world's population is increasing at an unprecedented rate. Worldwide, the number of individuals aged ≥65 years will more than double from ~506 million in 2008 to ~1,300 million by 2040, by which time people aged ≥65 years will account for 14% of the world's population.[1] Moreover, the world's population who are aged ≥80 years is projected to double by 2050.[1] Developing nations will experience the most rapid population ageing. The phenomenon of population ageing will lead to an increased proportion of the world's population having chronic age-associated diseases, such as osteoporosis.

Osteoporotic fractures are a major worldwide epidemic resulting in serious morbidity, disability, reduced quality of life and mortality.[2] Hip fractures are the most devastating type of osteoporotic fracture both for patients and health-care systems. Worldwide, the number of hip fractures is estimated to increase to 2.6 million by 2025, and reach 4.5 million in 2050.[3] These increases will be accompanied by high levels of morbidity and mortality, and increased economic burden on limited health-care resources.[4,5] The lifetime risk of any fracture of the hip, spine or forearm in the USA was estimated to be 40% in women and 13% in men.[6] In the UK, the lifetime risk of a hip, vertebral or wrist fracture for a 50-year-old women is 14%, 28% and 13%, respectively, and the corresponding risk for a 50-year-old man is 3%, 6% and 2%.[7] The worldwide economic cost of osteoporosis in 1998 was US$34.8 billion and is expected to rise to $131.5 billion by 2050.[8]

The lifetime risk of sustaining a vertebral fracture is higher than that for other types of osteoporotic fractures.[9] Excess mortality has been reported following vertebral fractures, whether or not they come to clinical attention because of pain.[10–12] Vertebral fractures are also associated with disability, chronic back pain, limitations to activities associated with daily living and reduced quality of life.[13,14] Other types of fractures are also associated with an increased risk of mortality and disability.[2] In the Dubbo Study from Australia, major osteoporotic fractures were associated with a 65% increase in mortality in women and a 212% increase in mortality in men.[15] Data from the Study of Osteoporotic Fractures showed that a wrist fracture increased the risk of a clinically important functional decline by 48%.[16]

This Review examines the global geographic variability in the three most prevalent types of osteoporotic fractures—hip, vertebral and distal forearm fractures. Ethnic disparity in fracture rates within a country and secular changes in fracture rates are also reviewed. We also explore possible factors that might contribute to the geographic variability in hip fracture rates globally. The geographic variability of osteoporotic fractures as a whole has been examined previously.[17–21]

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Key points

- Hip fracture rates increase with age, especially in women; rates in younger and older patients are not correlated, perhaps reflecting differences in the aetiology of hip fracture
- When comparing countries, age-standardized rates of hip fracture vary >200-fold in women and >140-fold in men; the hip fracture rate ratio in women to men is approximately 2:1
- Radiographic incidence of vertebral fractures is much higher than that of hip fractures, whereas the incidence of clinical vertebral fracture is similar to that of hip fractures in most countries where data are available
- Differences in the incidence of hip fractures between individuals of different ethnic backgrounds have been reported throughout the world
- Secular hip fracture rate declines have been reported since the 1990s in Europe, North America and Oceania; rates are increasing in Mexico and China but decreasing in Hong Kong and Taiwan
- Countries with higher socioeconomic development indices have higher hip fracture rates than less developed regions, suggesting that lifestyle might contribute to hip fracture risks

To examine geographic disparities in hip fracture incidence worldwide, 5-year age-specific and sex-specific rates from 50 countries were used to compute age-standardized hip fracture incidence rates in men, women and both sexes combined. Supplementary Table 1 provides the reference for each country, whether rates were based on national or regional data and the year when the data were collected. For countries without or with incomplete 5-year age-specific and sex-specific rates, standardized rates previously reported were used.[19] To ensure consistency in comparisons between countries the 2010 United Nations world population was used, which is the standard population used by several groups who previously examined geographic disparity in hip fracture rates.[18,19,22] A similar approach was taken for vertebral and forearm fracture, although these data are more limited compared with hip fracture data. To reveal factors that might contribute to the geographic variability in hip fractures, global indicators from the United Nations Development Program were also examined.[23]

Limitations of fracture data

Several methodological issues affect the comparability of the fracture incidence rates of different countries. These issues include whether the rates were standardized for age and sex, differences in study definitions of hip fracture, the methods used to identify individuals with hip fracture, and the generalizability of the populations used to generate national and ethnic-specific fracture rates. Secular changes in hip fracture rates can occur and, therefore, differences in the dates when the incidence rates were collected might influence any comparisons. Vertebral fractures are particularly problematic because most are not clinically apparent; only one-third[24] or one-fourth[25] of these fractures ever come to clinical attention. Many of the studies of vertebral fracture relied on hospitalization ICD-9 codes, which represent a small proportion of vertebral fractures because only an estimated 10% of individuals with vertebral fractures are hospitalized.[26] The comparability of data on morphometric or radiographic vertebral fractures is also limited owing to differences in the definition of prevalent and incident vertebral fractures between studies.

Fracture data standardized for age and sex are needed to accurately examine geographic and ethnic disparities. Studies differ in the age and sex composition of the study population; hip fracture incidence rates obtained from different time periods and from different ethnic groups are, therefore, not strictly comparable unless the age and sex differences between the study populations have been accounted for. Age and sex standardization is used to provide an estimated incidence rate in a given population as if that population had the same sex and age composition of an arbitrarily selected study population. Nevertheless, even studies that include age standardization treat individuals aged ≥80 years as one group. Fracture incidence rises exponentially with age and, therefore, the standardization process cannot adequately adjust for age if studies do not provide detailed data for individuals aged ≥80 years.

Another important consideration when comparing fracture data between countries is whether the study population is representative of the entire country. Fracture rates not only vary by country but also within a single region of that country. Considerable regional variation in hip fracture rates has been reported for the USA.[27] Rates of hip fracture among Hispanic individuals differed between those who lived in California[28] and New York.[29] Notable regional variation in hip fracture rates has also been described in Brazil, perhaps reflecting regional differences in ethnicity.[17] The use of national data from a population-based data set is, therefore, preferred over data from small regional studies within a country.[17]

Geographic disparities

Hip fractures

Age-specific incidence rates of hip fracture from 50 countries worldwide (Supplementary Table 2) vary by >200-fold in women, from the highest to the lowest incidence rate. These rates were available for one country in Africa,[30] 10 in Asia,[19,31–38] 24 in Europe,[21,39–48] six in Latin America,[19,49–54] five in the Middle East,[55–59] two in North America[60,61] and two in Oceania.[62,63] Globally, hip fracture rates increase with increasing age. The increase in incidence of hip fracture from ages 65–69 years to ≥85 years tends to be higher in women than in men in most countries. For example, the differences in incidence between these age groups are much larger in women than in men from Argentina,[49] Turkey[48] and New Zealand.[63] Exceptions include the USA[61] and Colombia[51], where the increase in hip fracture incidence with age is similar in both sexes, whereas the increase in incidence with age is higher in men than in women from Greece,[21] India,[33] Italy,[42] Iran,[55] Mexico,[53] Kuwait,[56] Australia[62] and Thailand.[35] More than a 15-fold increase in the incidence of hip fracture from ages 65–69 years to ≥85 years was observed in both sexes in Hong Kong,[32] Italy,[42] Venezuela,[54] Japan,[34] Portugal[45] and Canada.[60]

Age-specific rates of hip fracture were more strongly correlated among the older age groups (including

Table 1 | Correlations in age-specific hip fracture rates among men and women

Original data group (age in years)	Correlation for a particular age range in the opposite sex (years)							
	50–54	55–59	60–64	65–69	70–74	75–79	80–84	≥85
Men								
50–54	–	0.85*	0.77*	0.52*	0.42*	0.27	0.19	0.24
55–59	0.85*	–	0.87*	0.60*	0.48*	0.26	0.19	0.36*
60–64	0.77*	0.87*	–	0.69*	0.63*	0.41*	0.35*	0.43*
65–69	0.52*	0.60*	0.69*	–	0.85*	0.76*	0.68*	0.80*
70–74	0.42*	0.48*	0.63*	0.85*	–	0.89*	0.86*	0.73*
75–79	0.27	0.26	0.41*	0.76*	0.89*	–	0.96*	0.76*
80–84	0.19	0.19	0.35*	0.68*	0.86*	0.96*	–	0.75*
≥85	0.24	0.36*	0.43*	0.80*	0.73*	0.76*	0.75*	–
Women								
50–54	–	0.78*	0.59*	0.46*	0.11	0.33*	0.24	0.32
55–59	0.78*	–	0.80*	0.63*	0.28	0.45*	0.35*	0.36*
60–64	0.59*	0.80*	–	0.89*	0.65*	0.77*	0.69*	0.57*
65–69	0.46*	0.63*	0.89*	–	0.79*	0.90*	0.80*	0.62*
70–74	0.11	0.28	0.65*	0.79*	–	0.89*	0.74*	0.36*
75–79	0.33*	0.45*	0.77*	0.90*	0.89*	–	0.91*	0.67*
80–84	0.24	0.35*	0.69*	0.80*	0.74*	0.91*	–	0.86*
≥85	0.32	0.36*	0.57*	0.62*	0.36*	0.67*	0.86*	–

*Statistically significant (P<0.05). We used the age-specific hip fracture incidence rates shown in Supplementary Table 2 online. Pearson correlation coefficients were calculated.

individuals ≥75 years of age), than between the older and younger age groups (including individuals <60 years of age), in which only weak correlations were observed (Table 1). For example, the hip fracture incidence rates in women aged 80–84 years are not correlated with the incidence rates in women aged 50–54 years, but are highly correlated with rates in women aged 75–79 years. In our opinion, this difference might reflect different aetiologies of hip fracture in the younger and older age groups, that is, hip fractures in individuals aged 50–54 years are less likely to be osteoporotic than in individuals aged 80–84 years. In addition, as fewer fracture events occur in the younger than in the older age groups, the data for these younger age groups could be less reliable.

Age-standardized rates of hip fracture are available for 62 countries, including two in Africa,[19,30] 12 in Asia,[19,31–38] 28 in Europe,[19,21,39–48] seven in Latin America,[19,49–54] nine in the Middle East,[19,55–59] two in North America[60,61] and two in Oceania[62,63] (Figure 1; Supplementary Table 3). Median age-standardized rates of hip fracture in women were greatest in North America and Europe followed by Asia, the Middle East, Oceania, Latin America and Africa (Supplementary Table 3). A similar pattern was observed in men, with the highest median rates in North America and Europe and the lowest in Latin America and Africa.

Age-standardized rates of hip fracture in women are highest in Norway[43,44] and Denmark[21] and lowest in Nigeria[19] and South Africa[30] with a 265-fold difference in hip fracture rates between women from Nigeria and those from Norway. In men, age-standardized hip fracture rates were highest in Norway and lowest in Nigeria. Overall, the geographic variability in hip fracture rates seems lower in men than in women, although a 140-fold difference still exists between men in Norway and Nigeria. Despite this disparity, hip fracture rates in women and men showed that these rates were highly correlated, at $r = 0.86$ (P<0.0001). The age-standardized incidence of hip fracture in women is approximately twice than that in men, with some variability across the world. The median ratio of hip fracture rates in women to men is greatest in Latin America (2.4),[19,49–54] followed by Oceania (2.3),[62,63] North America (2.2),[60,61] Europe (2.0),[19,21,39–48] the Middle East (1.5)[19,55–59] and Africa (1.1).[19,30] Within regions, the ratio for hip fracture rates in women to men varies. For example in Asia, the ratio varies from 1.3 in Russia[36] to 2.9 in Indonesia;[19] in Europe, from 1.3 in Croatia[19] to 3.2 in Turkey;[48] in Latin America, from 1.8 in Columbia[51] to 3.1 in Argentina,[49] and in the Middle East, from 1.1 in Morocco[58] to 2.8 in Lebanon.[57]

Great variability in age-standardized hip fracture incidence in both men and women also occurs between different countries (Figure 1). For example, in Europe, the incidence of hip fractures in women ranges from 173 per 100,000 person-years in Poland[21] to 532 per 100,000 person-years in Norway.[43,44] In North America, hip fracture incidence in both men and women in Canada[60] is ~13% lower than that in the USA.[61] Hip fracture incidence in the USA and Northern Europe exceeds that in most countries in the world. Rates in Asian countries tend to be lower than those in Northern European countries in both men and women; however, hip fracture

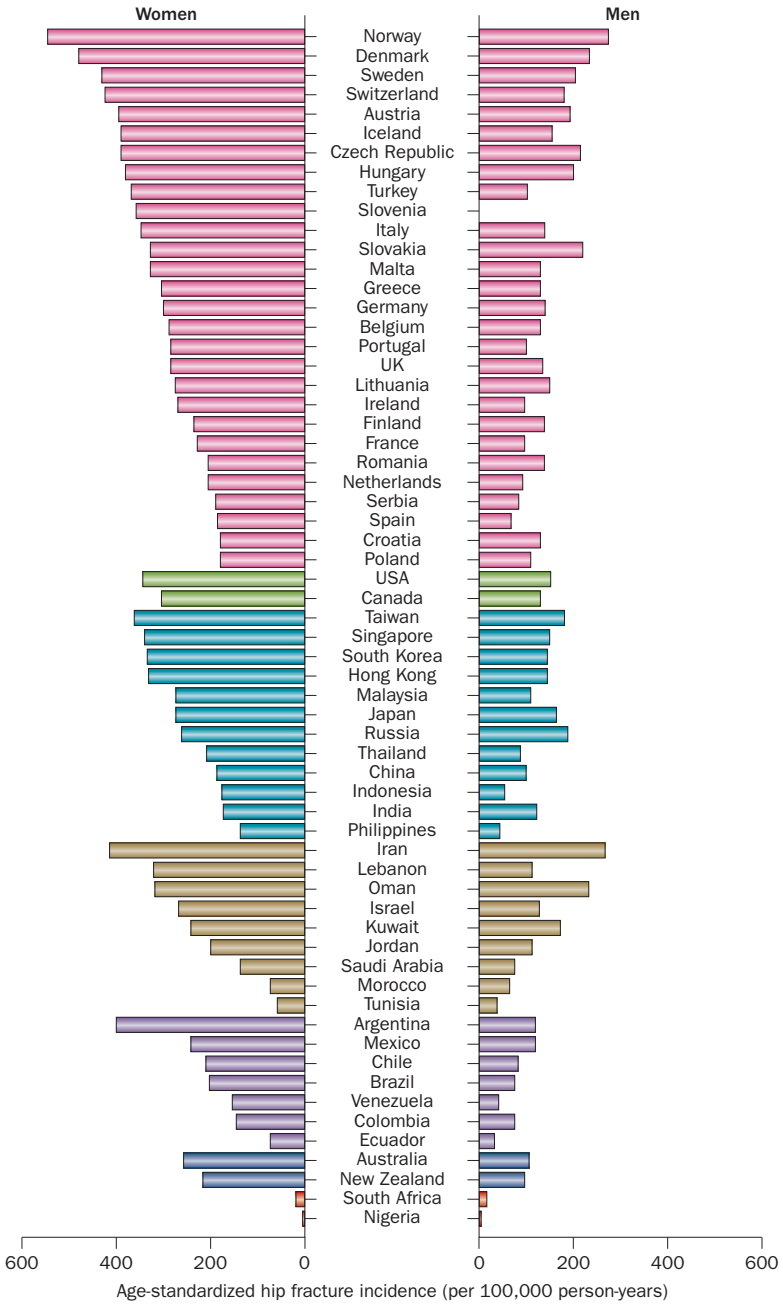

Figure 1 | Age-standardized hip fracture incidence rates in women and men according to country. Countries are organized by continent or geographic region: Europe (pink); North America (green); Asia (light blue); Middle East (brown); South America (purple); Oceania (dark blue); Africa (red). Data for each country were obtained from the references cited in Supplementary Tables 1 and 3.

incidence in women in Asia still ranges from 355 per 100,000 person-years in Taiwan[38] to 133 per 100,000 person-years in the Philippines.[19] In the Middle East, rates vary from 405 per 100,000 person-years in Iran[55] to 50 per 100,000 person-years in Tunisia.[19] Similar variations have been reported in Latin America, with the highest rates in both men and women in Argentina[49] and the lowest rates in Ecuador.[52] Rates of hip fracture in Australia and New Zealand are similar in men but rates tend to be higher in Australian[62] women than in New Zealand[63] women. Data from Africa are limited, with South Africa[30] and Nigeria[19] reporting very low rates such as 19 and 2 per 100,000 person-years respectively in men and women combined.

Worldwide, men have lower rates of hip fracture than white women from the USA (Figure 2). The high variability in hip fracture incidence in men in different countries in Europe, Asia and the Middle East is indicated by the wide range of ratio values obtained (Figure 2). In Europe, especially Northern European countries, women have higher rates of hip fracture than those of white women from the USA.[61] By contrast, hip fracture incidence in women from Latin America and the Middle East (with the exception of Argentina and Iran) is lower than in US white women. Women from Africa have very low hip fracture rates that are similar to those in men from Africa, although the available data are limited (Figure 2).

Vertebral and forearm fractures

Several studies have reported a similar prevalence of morphometric vertebral fractures in diverse geographic regions and countries. Studies using the same definition of morphometric vertebral fractures showed a similar prevalence (19–24%) in white women aged ≥65 years from Lebanon, the Netherlands, the USA and France.[17] The European Vertebral Osteoporosis Study measured the prevalence of vertebral fractures in individuals from 19 countries using standardized radiographic morphometric criteria.[64] The prevalence of morphometric vertebral fracture was 24% in men and 26% in women from Scandinavia, 21% in men and 19% in women from Western Europe, 18% in both men and women from Eastern Europe, and 22% in men and 23% in women from Mediterranean countries.[64] Interestingly, unlike hip fracture, these patterns suggest little difference in prevalent morphometric vertebral fractures between sexes. Indeed, the prevalence of radiographic vertebral fractures in Canada was also similar in men (19.8%) and women (20.9%).[65] By contrast, the prevalence of morphometric vertebral fractures was lower in Japanese men (3.2%) than in Japanese women (9.5%).[66]

Furthermore, prevalence rates were reported for women from five countries in Latin America.[67] The prevalence of morphometric vertebral fractures (using the same definition of morphometric vertebral fractures) for women (mean age 68.4 years) was 11.7% in Brazil, 14.5% in Argentina, 8.4% in Colombia, 10.6% in Puerto Rico and 15.7% in Mexico. Vertebral fracture prevalence rates of 25% were reported in Hong Kong and Beijing in China, and in Taiwan.[68]

The incidence of morphometric vertebral fractures is much greater than the incidence of hip fractures, especially if a prevalent vertebral fracture is present (see Supplementary Table 3 for comparison). In the European Prospective Osteoporosis Study (EPOS), the incidence of morphometric vertebral fractures in men and women, respectively, was 730 and 1,170 per 100,000 person-years in Scandinavia; 360 and 1,380 per 100,000 person-years in Southern Europe; 430 and 920 per 100,000 person-years in Eastern Europe; and 640 and 1,020 per

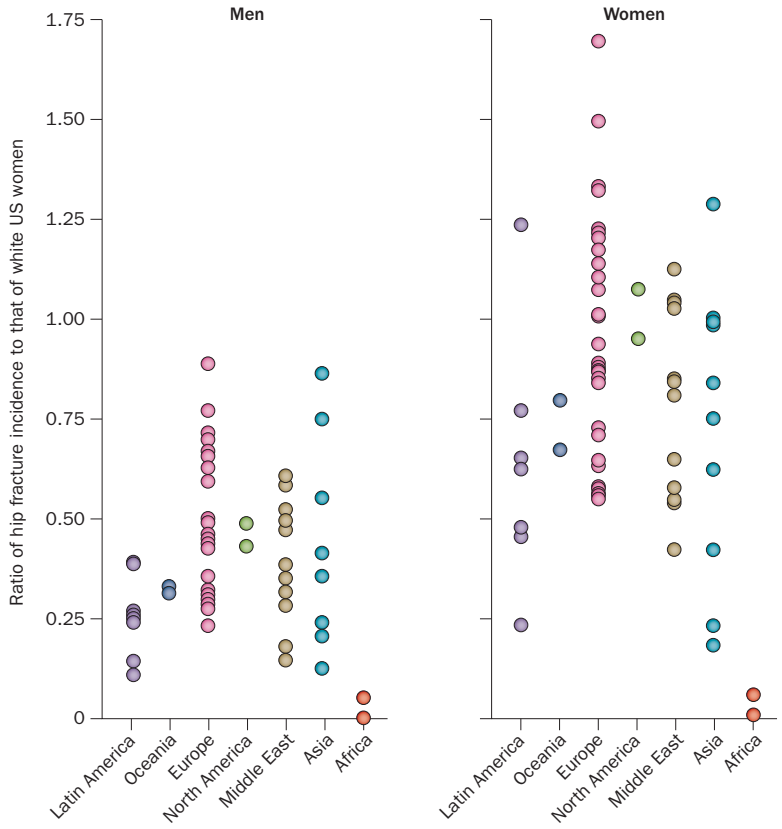

Figure 2 | Ratio of age-standardized hip fracture incidence compared with that of white women from the USA, according to country and organized by continent or geographic region in men and women. A ratio of ~1.0 indicates that the age-standardized incidence of hip fracture is similar to that in white women from the USA. Ratios of <1.0 indicate rates of hip fracture below those in white women from the USA and ratios >1.0 indicate rates of hip fracture above those in white women from the USA. The ratio of the hip fracture incidence rate was calculated using the Output Delivery System (ODS) Graphics Designer of SAS 9.3 (Cary, NC, USA). Countries are organized by continent or geographic region: Europe (pink); North America (green); Asia (light blue); Middle East (brown); South America (purple); Oceania (dark blue); Africa (red). Data for each country were obtained from the references cited in Supplementary Tables 1 and 3.

100,000 person-years in Western Europe.[69] Among white women from the USA, the annual incidence of morphometric vertebral fractures increased with age: 0.5% (65–69 years); 1.0% (70–74 years); 1.3% (75–79 years); and 1.7% (>80 years).[70] Over 15 years, data from the Study of Osteoporotic Fractures showed that 18.2% of white women in the USA aged ≥65 years experienced an incident morphometric vertebral fracture. The incidence was especially high in women with a prevalent vertebral fracture at baseline (41%).[71]

In the Rotterdam study, the incidence of morphometric vertebral fractures per 100,000 patient-years was 520 and 780 for those aged 55–65 years, 510 and 1,700 for those aged 65–75 years, and 930 and 1,960 for those aged ≥75 years in men and women, respectively.[72] Similarly to data from the USA, the incidence was much greater if a prevalent vertebral fracture was present; for example, in those aged ≥75 years, the incidence was 9,240 per 100,000 person-years in women with a prevalent vertebral fracture compared with 1,120 per 100,000 person-years if a prevalent vertebral fracture was not present (Supplementary Table 4).[72]

The incidence of radiographic vertebral fractures was very high in Thailand, with men having a 10-fold and women a 3-4-fold higher incidence than men and women in the Rotterdam study.[73] The incidence among Thai men was also substantially higher than that in Japanese men from Hiroshima.[66] The authors note that this higher incidence, especially among Thai men, might be due to trauma associated with strenuous physical activity owing to over half the individuals being labourers, farmers and street vendors.

To the best of our knowledge, the only countries with published incidence rates of clinical vertebral fractures are Australia,[74] Hong Kong,[75] Hungary,[40] Sweden,[76] Switzerland[47] and the USA[61] (Supplementary Table 4). Notably when evaluating these rates, most of the fractures have been identified using hospital discharge codes or radiographic databases. Rates of clinical vertebral fractures increase with age in both men and women. Clinical vertebral fracture rates are considerably lower than radiographic vertebral fracture rates in all countries listed. Unlike hip fracture rates, those for clinical vertebral fractures are higher in Asian countries of Hong Kong than in Europe or the USA. Rates of clinical vertebral fractures are higher in Sweden and Switzerland than in the USA. Comparison of age-standardized hip and clinical vertebral fracture rates show they are similar in Australia, Sweden, Switzerland and the USA (Supplementary Tables 3 and 4). The data on clinical vertebral fractures from Hungary are suspicious since these rates are considerably lower than those observed for hip fracture in Hungary.[40] This discrepancy might reflect an ascertainment bias resulting in many clinical vertebral fractures not being captured. In summary, there seems to be less worldwide variability in prevalent morphometric vertebral fractures than in clinical vertebral fractures. Interpretation of the geographic disparity of clinical vertebral fractures is difficult given the variable definitions of vertebral fractures, incomplete ascertainment of cases and the limited data from a small selection of countries.

The incidence of forearm fractures in Australia,[74] Hungary,[40] Japan,[77] Russia,[36] Sweden,[76] Switzerland,[47] the UK[78] and the USA[61] has been reported (Supplementary Table 5). Standardized definitions were not applied, as incidence rates of forearm, distal forearm or Colles fractures were reported. Fracture rates increased with age in women but not in men (Supplementary Table 5). Age-standardized rates of distal forearm fractures were particularly low in Japan,[77] whereas very high rates were reported in Hungary.[40]

Ethnic disparities

Hip fractures

Limited data are available on ethnic disparities in fracture rates within a country. Ethnicity influences osteoporotic fracture risk (Supplementary Table 6),[63,79,80] therefore, interpreting fracture rates in an ethnically diverse country and in countries that are experiencing increased immigration can be problematic. For example,

in Norway, population projections suggest that immigrants from Africa, Asia, Turkey and Latin America will increase from 200 per 1,000 in 2005 to 820 per 1,000 by 2060.[81] Future country-specific fracture data analysis will, therefore, need to consider the increasing ethnic heterogeneity of the country's population. Future hip fracture rates in some countries could differ from the current rates because of the rapidly changing landscape of ethnicity within these countries.

In the USA, age-adjusted hip fracture rates among women ≥65 years of age of different ethnicity are highest in white women and lowest in black women (Supplementary Table 6).[79] In general, rates in women ≥65 years of age in the USA are ~50% lower in individuals of Black and Asian ethnicity than in those of white ethnicity, and ~30% lower in individuals of Hispanic ethnicity than in those of white ethnicity.[79] Black and Asian men <75 years of age in the USA have the lowest hip fracture rates.[79] Among men of this age group in the USA, a pattern similar to that in women emerges, with black, Asian and Hispanic men having a 40%, 55% and 30% lower hip fracture rate, respectively, than white men.[79] Another analysis found that age-adjusted hip fracture incidence rates in individuals ≥65 years of age in the USA were lower for all individuals of Asian ethnicity (Chinese, Japanese and Korean Americans) than for white individuals.[82] Within the USA, the female-to-male ratio of hip fracture is 1.86 in non-Hispanic white individuals, whereas among black individuals the female-to-male ratio is only 1.16.[79] The corresponding female-to-male ratios for Asian and Hispanic populations are 1.89 and 1.62, respectively.[79]

A report of the hip fracture incidence rates in individuals aged ≥50 years in different ethnic groups in Singapore from 1991 to 1998 revealed age-specific and age-adjusted rates that were highest in Chinese, followed by Indian and then Malay men and women (Supplementary Table 6).[80] Sex differences in age-adjusted hip fracture rates were quite large in the study, especially among Malay and Indian men and women. Age-adjusted hip fracture rates in Chinese individuals living in Singapore in 1991–1998 were greater than those more recently (1996–2000) reported in Chinese individuals living in Beijing,[31] but were comparable to rates reported in Taiwanese individuals;[83] however, these differences could reflect the years in which data were collected. Indian women living in Singapore had an age-adjusted rate of hip fracture that was two-fold higher than that in a more recent study of women from a single district in Northern India.[33] The difference might relate to regional differences in hip fracture rates across India and highlight the issue of reporting rates for a country using a national database versus a regional one.

New Zealand has also published hip fracture rates in four distinct ethnic groups. Among the population aged >65 years, 90% of individuals are of European descent, and the remaining are of Maori (5%), Asian (4%) and Pacific Islander (2%) ethnicity.[84] Age-specific hip fracture rates tend to be 30% higher among New Zealanders of European descent than for Maori, Pacific Islander and Asian individuals (Supplementary Table 6). Within each ethnic group in New Zealand, fracture rates are 70% higher in women than in men.[63]

Other fractures

Data on ethnic differences in the rate of other fractures are limited to North America. Significantly higher rates of any fracture among First Nations Canadians than in sex-matched and age-matched white Canadians have been reported.[85] The standardized incidence ratios for each fracture type in First Nations Canadians compared with incidence rates in white Canadians were 1.88 for hip fracture, 3.01 for wrist fracture, 1.93 for spine fracture and 2.23 for any fracture. Data from the 1990s in the USA indicated lower rates of distal forearm and proximal humerus fracture in black individuals than in white individuals.[86–88] In a 2007 report, the incidence of nonspine fractures was 1,090, 580, 3,170, and 1,680 per 100,000 person-years in white men, black men, white women and black women, respectively, in individuals 70–79 years of age.[89] However, the number of fractures was very low in black individuals: 11 fractures in men and 39 fractures in women.

Minimal data are available on fracture rates in American Indians. For women aged 50–79 years enrolled in the Women's Health Initiative, the rate of all clinical fractures was similar in American Indian women and white women.[90] Clinical fracture rates per 100,000 person-years were 2,000, 900, 1,300, 1,200 and 2,000 in women of white, black, Hispanic, Asian and American Indian ethnicity, respectively.[90] In the National Osteoporosis Risk Assessment study, individual fracture rates were not provided but the risk of fracture compared with that in white women had an hazard ratio of 0.54 (95% CI 0.41–0.72) for black women, 0.89 (95% CI 0.59–1.30) for Native American women, 0.91 (95% CI 0.72–1.15) for Hispanic women and 0.41 (95% CI 0.21–1.79) for Asian women.[91] The prevalence of vertebral fractures is about 50% lower in US black women than in white women.[92]

Secular changes in fractures

Hip fractures

A summary of global secular changes in hip fracture (Table 2) has been reviewed previously.[93,94] In the USA,[95] Canada,[96] Norway,[44] the UK,[97] Greece,[98] Netherlands,[99] Sweden,[100,101] Crete[102] and Switzerland[103] hip fracture rates increased up to the mid-1990s. In the countries in which data after the mid-1990s are available (all but Greece and Crete), hip fracture rates declined, especially in women. This trend suggests sex-specific differences in the underlying cause of secular changes. From 2000 to 2009, declines have also been seen in Belgium,[104] Australia,[62] Ireland[105] and Denmark.[106] Rates of decline in hip fracture incidence ranged from 20% to 35% in women and from 13% to 25% in men depending on the country. The average annual decline is ~1.0–2.5% per year. The year in which the rate of hip fracture incidence started to decline occurred somewhat later in the Czech Republic (2004) and Austria (2005 in women and 2006 in men) than in other countries.[39,107] In Austria, a study

Table 2 | Secular changes in hip fracture by country

Country	Years	Secular trends
Australia[62]	1997–2007	Hip fracture rates declined by 20% in women and by 13% in men (both $P \leq 0.05$)
Austria[107]	1989–2008	Hip fracture rates increased until 2005 in women and 2006 in men and, thereafter, declined ($P < 0.01$ in women; $P < 0.15$ in men)
Belgium[104]	2000–2007	Hip fracture rates declined 1.12% per year in women ($P < 0.05$) and 0.34% per year in men (P not significant)
Canada[96]	1985–2005	Hip fracture rates declined an average of 32% in women and 25% in men Rate of decline increased after 1996: 1985–1996, 1.2% annual decline versus 1996–2005, 2.4% annual decline (all $P \leq 0.001$)
China[31]	1990–2006	Hip fracture rates increased 2.76-fold in women and 1.61-fold in in men (both $P < 0.05$); from 2002 to 2006 rates increased by 58% in women and by 49% in men
Crete[102]	1982–1986	Annual number of patients with a hip fracture increased by 2%
Czech Republic[39]	1981–2009	Hip fracture rates increased to 2004 then decreased after 2005
Denmark[106]	1997–2006	Incidence rates of hip fracture declined by 20% in men and by 22% in women
Germany[144]	1995–2004	Hip fracture rates increased 9% in men and 2.7% in women (both $P = 0.01$)
Greece[98]	1977–1992	Hip fracture incidence increased by 81% in men and women
Hong Kong[111]	1995–2004	Hip fracture rates decreasing with the most marked decrease in the 50–59 year age group
Iceland[41]	1989–2008	Hip fracture rates increased in men until 2001 when they levelled off; the incidence rate was 40% higher in men in 2005–2008 than the rate in 1989–1992. In women, hip fracture rates increased in 1989–2000 then declined, with the incidence rate being 20% lower in 2005–2008 than in 1997–2000
Ireland[105]	2000–2009	In women, a decline in hip fracture incidence of 1.25% per year ($P = 0.003$); no significant change in men
Japan[34]	1987–2007	Hip fracture incidence 1.97 higher in women and 1.66 higher in men in 2007 compared with 1992
Mexico[53]	2000–2006	Hip fractures rates increased by 1% per year in both men ($P = 0.016$) and women ($P < 0.001$)
Netherlands[99]	1981–1993	Hip fracture rates increased in 1981–1993, with an annual percent change of 2.2% in women and 2.5% in men
New Zealand[115]	1974–2007	Age-adjusted hip fracture rates increased for women from 1974 to 1987 and then declined until 2007, whereas rates for men increased from 1974 to 2007
Norway[44]	1978–2007	Hip fracture rates increased from 1978; a 35% decline was observed in women and a 6% decline in men since 1997
Sweden[100,101]	1987–1996	Hip fracture rates increased for all age-specific and sex-specific groups with larger increases in men
	1994–2008	Hip fractures rates declined in 1994–2008; the annual percent change was –0.64% in women and –0.34% in men
	1998–2009	Hip fracture rates declined in all age-specific and sex-specific groups, especially among women and younger men; the change in incidence in women and men aged 65–79 years was –34% and –24%, respectively, and in women and men aged ≥80 years was –22.5% and –0.7%, respectively
Switzerland[103]	1991–2000	Age-adjusted incidence of hip fractures decreased significantly by 1.4% per year in women but remained stable in men (0.5% per year)
Taiwan[83]	1996–2002	Incidence of hip fracture increased in men by 36% and in women by 22%
Taiwan[110]	1999–2010	Age-standardized hip fracture hospitalizations decreased by 2.7% annually, especially among those aged >75 years (6.1% decline)
UK[97]	1968–1986	Hip fracture rates increased over this time period in both men and women
USA[95]	1986–2005	Hip fracture rates increased 9% in women and 16.4% in men from 1986 to 1995, especially in older individuals. Hip fractures rates decreased by 24.5% in women and by 19% in men in 1996–2005

examining secular changes in the hip fracture incidence rate showed a 13% increase from 1994 to 2006, and the rate of increase over this time period was significantly higher for men than for women.[108] The incidence rate ratio when rates in 1994 were compared with rates in 2006 was 1.21 (95% CI 1.16–1.27) in men and 1.10 (95% CI 1.06–1.14) in women ($P = 0.03$).[108]

Increasing rates of hip fracture have been reported in Mexico, with a 1% increase per year from 2000 to 2006.[53] Furthermore, an increasing incidence of hip fracture was reported in Japan, with the incidence being 1.96 times higher in women and 1.66 times higher in men in 2007 than in 1987.[34] Similar increases in hip fracture incidence were reported from 1986 to 2001 in another

study from Japan.[109] In Beijing, China, hip fracture rates have increased 2.76-fold in women and 1.61-fold in men between 1990 and 2006.[31] Hip fracture rates increased 58% in women and 49% in men over just 4 years, 2002–2006. In Taiwan, hip fracture incidence increased by 22% in women and by 36% in men from 1996 to 2002,[83] but a later report analysed rates from 1999 to 2010 and showed a 2.7% annual decline.[110] Similarly, hip fracture rates declined in Hong Kong between 1995 and 2004,[111] perhaps because of secular increases in BMD.[112]

Within the USA, ethnic-specific secular changes from 2000 to 2009 have been reported.[79] Hip fracture rates declined by 11.6% ($P = 0.046$) in white women, 10.7% ($P = 0.22$) in black women, 11.4% ($P = 0.17$) in Asian women and –2.9% ($P = 0.72$) in Hispanic women, although the decline was statistically significant only in white women. Smaller declines than those in women were observed in men of all four ethnic groups. Similar to the trends in women, the decline was statistically significant only in white men, with variations of –3.6% ($P = 0.4$) in white men, –4.3% ($P = 0.28$) in black men, –7.1% ($P = 0.42$) in Asian men and +2.8% ($P = 0.46$) in Hispanic men. Irrespective of sex, the largest declines in hip fracture rates from 2000 to 2009 were observed in individuals >75 years of age in the USA. For example, the average change in hip fracture rate in white women and men aged <75 years was –2.4% and –3.3%, respectively, whereas the rate change for white women and men aged ≥75 years was –24.5% and –13.3%, respectively. These national data do not support the findings of a Californian study of hospital discharge data, which reported an increase in hip fracture rates in Hispanic individuals in the USA from 1983 to 2000.[113]

Most data on secular trends of hip fracture comes from Europe, North America and Oceania.[44,93–108] Generally, increases in hip fracture incidence have been observed through the second half of the 20th century, with declines in the 21st century. The limited data from Asia suggest a different pattern, with fracture rates continuing to increase into the 21st century, particularly in China; however, rates decreased in Hong Kong and Taiwan.[31,83,109–111] Little is known about secular changes in fracture rates in the Middle East, Africa, Latin America (except for Mexico[53]) and most countries in Asia. The lack of information in certain countries, such as India and Indonesia, has important public health implications because these countries have a rapidly ageing population. India is the second most populous country after China and is in the early stages of transitioning to an older (≥65 years of age) society. The bulk of hip fractures in the world will occur in Asia by the year 2050 because of the demographic shift to an ageing society, huge population growth and increasing hip fracture rates.[93] More information is, therefore, needed on secular changes in hip fractures using national representative databases and information on risk factors to address the rising number of hip fractures in these countries.

Cohort effects

The term 'cohort effect' is used to describe changes in a characteristic, in this case, hip fracture, over time. Rates of hip fracture could be declining because cohorts from studies in the past few decades are generally healthier than earlier cohorts. The change might reflect a shared temporal experience or common life exposure, such as birth year. For example, men and women born before 1945 experienced two world wars and a large economic depression, experiences that might influence health later in life.

In Sweden, the effect of a birth cohort on hip fracture rates was more marked in women than in men.[101] Women in birth cohorts born in 1926–1936 and earlier had substantially higher relative cohort-specific hip fracture incidence rates than their counterparts in more recent birth cohorts (1945–1952). These Swedish birth cohort effects are probably multifactorial, with nutrition and physical activity as major factors. Failure to reach peak skeletal mass within a person's genetic makeup because of poor nutrition in childhood or adolescence could influence the risk of hip fracture later in life.[114] The cohort effects were stronger in women than in men, which suggests that reproductive factors such as age at menarche, parity or use of hormone therapy have a role in these effects.[101] The authors of the study note that the Swedish government health authority instigated a number of social and health reforms, supplying doctor-led health services and regular health care and nutritional evaluations for children from birth to age 7 years in the first part of the 20th century.[101] These preventive services could have led to improvements in bone strength and reduced hip fracture rates in successive birth cohorts. A different pattern was reported for New Zealand, where higher hip fracture rates were noted in individuals from the more recent birth cohort (1948–1957) than in those from the earlier birth cohort (1873–1882).[115]

A birth cohort effect related to hip fracture rates was also reported for the Framingham cohort from the USA.[116] Women born in 1911–1921 had a 40% greater incidence of hip fracture than women born in 1887–1900. Men born in 1911–1921 had a two-fold higher risk of hip fracture than men born in 1887–1900.[116] Over this time period, the increasing hip fracture incidence is consistent with improvements in life expectancy.[1] Long-term follow-up of additional birth cohorts in the USA and elsewhere is needed to determine whether the decline in rates observed in successive birth cohorts in Sweden has also occurred in the USA and elsewhere.

Other fractures

Limited data are available on secular changes in other fractures. In Iceland, major osteoporotic fracture rates increased from 1989 to 2001 and then began to decline, similar to hip fracture rates.[41] Vertebral fracture rates declined by 31% in men and by 15% in women from 1989 to 2008, and wrist fracture rates doubled in women from 1989 to 2000 before declining by 19% by 2008.[41] Data from Minnesota in the USA showed that the age-adjusted incidence of clinically ascertained vertebral fractures increased ~80% from 1980 to 1989.[117] Clinical vertebral fracture rates reported using data from a large US insurance claims database were stable from 2000

to 2005.[118] Little is known about secular changes in the incidence of morphometric or radiographic vertebral fractures. In Sweden, the incidence of radiographically diagnosed vertebral fractures increased from 1950 to 1983.[119] The pattern for wrist fracture rates seems to resemble that for hip fracture rates; for example, rates of both wrist and hip fractures declined between 1997 and 2000 in Canada[120] and Australia.[121] This observed decline in the rate of other types of fractures that parallels the decline in hip fracture rates is consistent with the aetiology of fractures, that is, most fractures are due to low BMD and falls.

Factors underlying secular declines

The precise factors that are responsible for the secular declines in hip fracture rates in the past few decades are unknown. The secular declines in hip fracture rates in most developed countries coincided with the approval of bisphosphonates for the treatment of osteoporosis. In Belgium, a high negative correlation between age-standardized hip fracture incidence rates and prescriptions for antiosteoporosis medication has been observed,[104] although a causal association has not been established. Brauer *et al.* estimated that the increase in bisphosphonate use would account for a 9% reduction in hip fracture incidence in the USA observed from 1995 to 2005, that is, only 40% of the observed 23% reduction.[95] However, in Denmark, the number of prevented hip fractures that could be attributed to osteoporosis therapy was estimated to be 11.3% in men and 3.7% in women.[106] The use of approved medications might, therefore, contribute to, but not totally account for, the observed secular declines in hip fracture rates.

The epidemic of obesity could also contribute because individuals with obesity have reduced hip fractures rates; however, evidence from the past few years suggests that obesity is not protective once adjustments for BMD have been made and/or other concomitant deleterious effects on bone, such as inflammation, are accounted for.[122] Secular increases in BMD have also been reported, but these data are limited to the USA and Hong Kong and would not necessarily apply worldwide.[112,123] Worldwide secular increases in rates of obesity parallel increases in rates of insulin resistance and type 2 diabetes mellitus (T2DM). The epidemic of T2DM could potentially reverse some of the secular declines in hip fracture rates worldwide because this disease is a major risk factor for fracture.[124]

Lifestyle factors might have contributed to the observed decline in hip fracture rates in the developed world over the past few decades. For example, declines in smoking, and increases in physical activity and the use of calcium and vitamin D supplements might have influenced outcomes. Declines in hip fracture rates in Geneva, Switzerland, have been linked to a decrease in the incidence of fractures in institutionalized elderly women.[125] The authors of this study hypothesize that this change might relate to an improvement in fall prevention and a reduction in vitamin D deficiency. Despite the decline in hip fracture rates, the age of patients with a hip fracture is increasing as are comorbidities, therefore, the effect of hip fracture on disability might also be increasing.[19]

Improvements in nutrition during pregnancy and childhood might contribute to the secular declines observed in hip fracture rates in most developed countries over the past few decades. For example, in birth cohort studies, vitamin D insufficiency during late pregnancy might influence the bone mass and muscle mass of children.[126,127] Moreover, changes in socioeconomic status might also contribute to changes in fracture rates. A high prevalence of unhealthy behaviours, for example, smoking in low socioeconomic status groups during adulthood, contributed to disparities in hip fracture rates later in life in the Netherlands.[128] Low socioeconomic status in developing countries such as China might, therefore, contribute to their increasing hip fracture rates. Increasing urbanization and resultant declines in physical activity and employment in sedentary jobs might also contribute to increasing hip fracture rates in these countries.[31]

Geographic disparity

The >200-fold variation in hip fracture incidence across the world raises important questions about the aetiology of hip fracture. The reasons for this variability are unknown, but genetic, environmental and lifestyle factors probably all influence this disparity. In twin and family studies, 50–80% of the variance in BMD is genetically determined and BMD is the single best predictor of fracture after age.[129] Osteoporotic fractures have also been shown to be heritable independent of BMD, but the heritability of fracture is much lower than that of BMD, reflecting the heterogeneity in the aetiology of fracture (that is, both bone-related and fall-related factors).[130] A genome-wide association analysis of almost 83,000 individuals identified 56 loci associated with BMD and 14 loci associated with fracture risk.[131] Some of the variants associated with BMD were not associated with fracture. For example, variants in the RANK–RANKL–osteoprotegerin pathway were clearly associated with BMD but were unrelated to fracture.[131] The international variability in fracture rates might, therefore, partly reflect differential genetic susceptibility across countries.

In this Review we hypothesize that global indicators of socioeconomic status, life expectancy, government spending on health, and urbanization might contribute to the worldwide differences in hip fracture rates. Associations between these global indicators of development and age-standardized hip fracture rates are modest but all significant (Table 3). Correlations tend to be stronger in women than men, perhaps because of a larger range in hip fracture rates in women than in men. The strongest correlations are observed for the Human Development Index, a composite measure that reflects dimensions of health, education and living standards within each country. Surprisingly, public expenditure on health explains little of the variance in hip fracture rates—countries increased spending did not lower their hip fracture rates. Urbanization has been hypothesized to contribute to secular increases in hip fracture rates

in developing countries but the correlation with age-standardized rates is modest, at 0.22 in men and 0.35 in women (Table 3).

Correlation between gross national income (GNI) per capita and age-standardized rates of hip fracture across the world are shown in Figure 3a. Hip fracture rates tend to be highest in countries with the highest GNI per capita, such as some countries in Europe and North America. Asian countries with low GNI per capita, for example the Philippines,[19] have lower age-standardized rates of hip fracture than Asian countries with high GNI per capita, for example Singapore.[35] Similarly, age-standardized hip fracture rates are generally positively correlated with the Human Development Index (Figure 3b). Little variability in life expectancy exists for the countries included, except for the two countries in Africa that have low life expectancies (Figure 3c). Life expectancy is positively correlated with hip fracture rates, but the correlation is weak after exclusion of the two countries in Africa. In summary, and in support of our hypothesis, a country's level of development can affect the incidence of hip fractures; however, much of the geographic disparity in hip fracture rates remains unexplained.

Given the importance of BMD as a major predictor of fracture in both men and women, geographic variability in BMD owing to genetic and/or environmental factors could contribute to geographic differences in fracture rates. Many reports of ethnic differences in BMD are limited to ethnic groups in the USA.[132,133] However, two reports compared standardized areal BMD measures in men and women aged ≥65 years from several different ethnic populations in the USA, as well as individuals from Hong Kong, Tobago and South Korea.[131,132] Hip BMD in men from Tobago was 8–10% higher than that in black men from the USA, despite the fact that both populations are of African origin.[134,135] This difference might reflect the greater European admixture of US black men than that of Afro-Caribbean men, but the rural lifestyle in Tobago might also have contributed. Between the Asian individuals studied, BMD was much lower in South Korean men than in men from Hong Kong. The South Korean men experienced nutritional deficits during the Korean War (1950–1953) when in their childhood and adolescence, which might have led to low peak skeletal mass.

In women, age-adjusted BMD hip measurements were 21–31% higher in Afro-Caribbean women and 13–23% in African American women that in white women in the USA.[135] However, unlike the data in men, BMD was significantly higher in South Korean women than in women in Hong Kong, even after adjusting for age, body weight and other covariates. In general, BMD differences were smaller when comparing both Asian groups to white women from the USA. The prevalence of postmenopausal hormone therapy was much higher in women from the USA and contributed to the differences in BMD between the USA and other countries.[135]

Secular changes, and geographic differences, in the height of individuals between different countries might contribute to the wide variability in hip fracture rates globally. A study of 364,538 women from 54 low-income to middle-income countries who participated in the Demographic and Health Surveys, such as Armenia and Turkey, indicated an overall increase in height in middle-income individuals born after 1945, whereas low-income countries experienced an overall loss of height.[136] The increase in height in the wealthier countries is probably due to improved nutritional status, which might lead to increased peak skeletal mass and a decline in hip fractures rates. Geographic differences in other anthropometric parameters (weight) and bone size are also important. For example, differences in hip fracture rates between Asian and white individuals cannot be explained by lower areal BMD because generally Asian women have similar BMD to white women despite their lower body weight.[132] Moreover, Chinese women have a small appendicular skeleton with more mineralized bone, thicker cortices and lower cortical porosity, whilst trabeculae are fewer but thicker and more connected in comparison with white women.[137] These additional skeletal features might, therefore, contribute to geographic differences in fracture rates.

Differences in physical activity and diet might also contribute to the variability in hip fracture rates across the world. In one study, South Korean men had a lower dietary calcium intake than men from Hong Kong or Asian men living in the USA.[134] Differences in physical activity could underlie the differences in hip fracture rates in urban and rural settings. For example, the authors of one study hypothesized that the rapidly increasing

Table 3 | Hip fractures and development indicators

Variable	Pearson's correlation coefficient	*P* value
Men		
Human Development Index	0.52	<0.001
Life expectancy at birth (years)	0.42	0.001
GNI per capita (US$)	0.52	<0.001
Mean years of schooling of adults (years)	0.45	<0.001
Public expenditure on health (%)	0.33	0.010
Urban population (%)	0.22	0.090
Women		
Human Development Index	0.66	<0.001
Life expectancy at birth (years)	0.58	<0.001
GNI per capita (US$)	0.59	<0.001
Mean years of schooling of adults (years)	0.54	<0.001
Public expenditure on health (%)	0.46	<0.001
Urban population (%)	0.35	0.006

Life expectancy at birth is defined as the number of years a newborn infant could expect to live if current age-specific mortality rates at the time of birth remain stable throughout the infant's life. GNI is a country's income generated by its production and its ownership of factors of production, after deducting income paid for imports and taxes. GNI per capita is GNI divided by mid-year population. Mean years of schooling of adults, life expectancy at birth and GNI contribute to the calculation of Human Development Index. Abbreviation: GNI, Gross National Income.

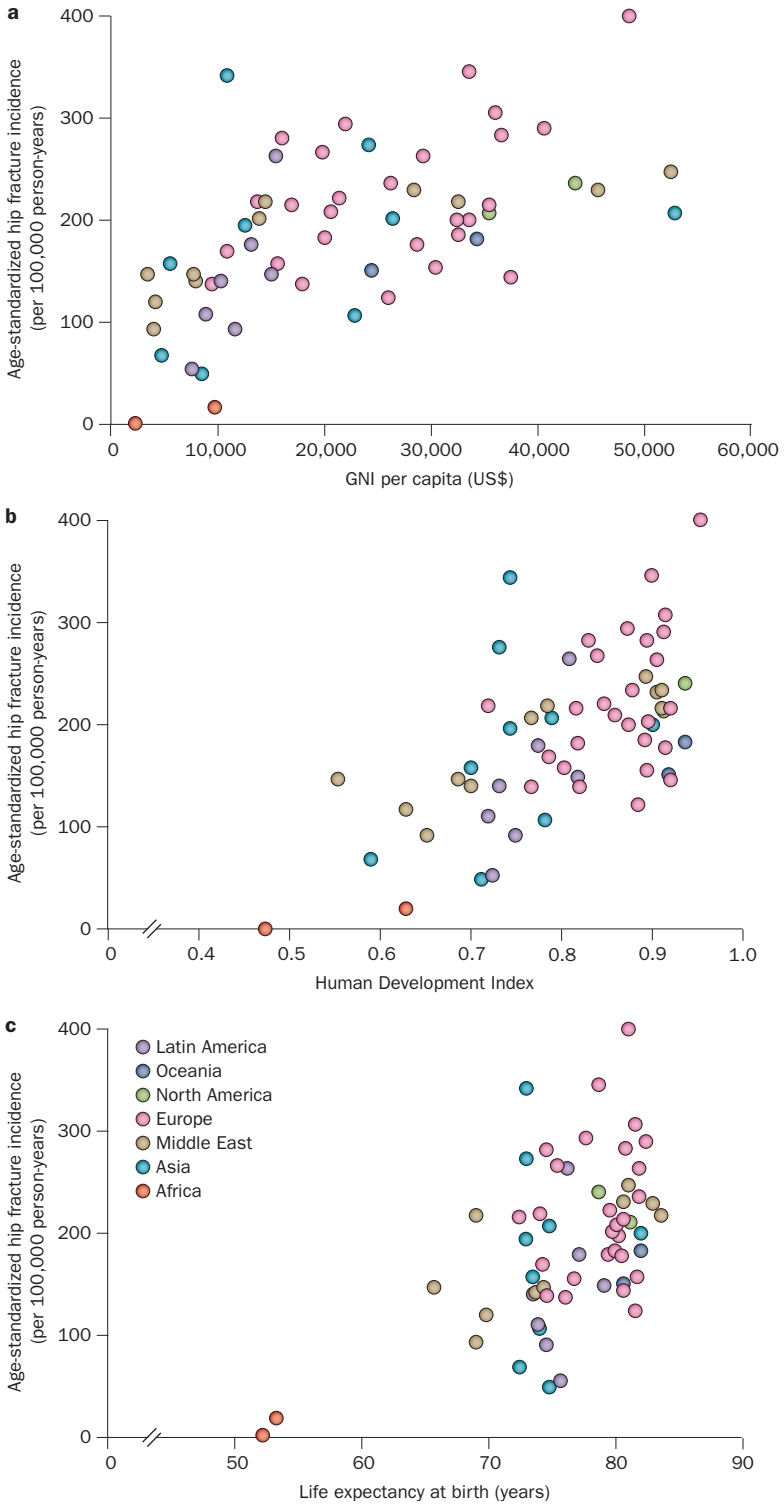

Figure 3 | Correlation between age-standardized hip fracture incidence rates in men and women combined and GNI per capita, Human Development Index or life expectancy at birth. **a** | Standardized hip fracture rates as a function of GNI. **b** | Standardized hip fracture rates as a function of the Human Development Index. **c** | Standardized hip fracture rates as a function of life expectancy at birth. These plots were generated using the ODS Graphics Designer of SAS 9.3 (Cary, NC, USA). Countries are organized by continent or geographic region: Europe (pink); North America (green); Asia (light blue); Middle East (brown); South America (purple); Oceania (dark blue); Africa (red). Data for each country were obtained from the references cited in Supplementary Tables 1 and 3. Abbreviation: GNI, Gross National Income.

rates of hip fracture in Beijing could reflect increased urbanization, which is characterized by increased reliance on cars and buses instead of walking or cycling.[31] In addition, other changes in urban environments, such as the increase in hard surfaces, sitting in chairs rather than on the floor, and substituting Western-style toilets for traditional squat toilets might also contribute to ethnic differences in fractures.[31] These environmental factors related to urbanization might help to explain the large differences in hip fracture rates in genetically similar and geographically close populations, such as Han Chinese individuals living in Beijing[31] or Taiwan.[83]

Geographic differences also exist in hormonal factors that are known to influence bone homeostasis. For example, the prevalence of vitamin D deficiency varies across the world. The prevalence of vitamin D insufficiency (defined as <75 nmol/l) in several studies was ~50% in Thailand and Malaysia, ~70% in the USA, and ~90% in Japan and South Korea.[138,139] However, information on vitamin D status in populations around the globe is missing.[140] Clinical trials evaluating the effects of vitamin D supplementation on skeletal outcomes in countries where the circulating levels of vitamin D are low are needed.

Substantial geographic variation also exists in the levels of sex steroid precursors and metabolites and sex-hormone binding globulin.[141] Differences in the genetics of sex steroid metabolism in different ethnic groups might or might not be reflected in differences in circulating levels of sex steroids. Nevertheless, this observed geographic variability in circulating sex steroid hormone levels, which are major aetiological factors for osteoporotic fractures, might contribute to the international variability in fractures.

Most fractures occur because of a fall, and the incidence of falling and differential risk factors for falling might also contribute to geographic disparities. In Europe, fall rates vary in men and women 50–79 years of age, from just 5 per 100 person-years in Rotterdam, Netherlands, to >20 per 100 person-years in Oslo, Norway.[142] Comorbidity has a major influence on osteoporotic fractures. Individuals with increased comorbidity have a high risk of fractures. Among these, T2DM is a major risk factor for fractures including hip fracture, and the prevalence of diabetes mellitus varies dramatically across the world.[143] For example, the prevalence of diabetes mellitus was about 35% in New Guinea and about 10% in China and India,[143] which could contribute to geographic variability in hip fracture rates.

Conclusions

Across the world, hip fracture rates increase with age but the magnitude of the increase tends to be higher in women than in men. Correlations in hip fracture rates in older (age ≥75 years) versus younger (age <60 years) individuals are modest, which suggests differences in the aetiology of hip fracture in these two age groups. Worldwide, a 265-fold and 140-fold variability in hip fracture rates exists in women and men, respectively, comparing the highest-incidence with the lowest-incidence country.

Interpretation of global variability in both clinical and radiographic vertebral fractures is difficult because of varying definitions and ascertainment methods used in different studies. Radiographic vertebral fracture prevalence rates seem to be similar in men and women. Geographic patterns of clinical vertebral fracture rates tend to mimic those of hip fracture rates. Overall, the incidence of radiographic vertebral fractures is much higher than the incidence of hip fractures, while the incidence of clinical vertebral fractures and hip fractures seems to be similar in most of the countries where data are available. Intra-country ethnic differences in hip fracture rates have been published for the USA, Singapore and New Zealand. Research is needed to elucidate the effects on hip fracture rates of changes in the ethnic composition of countries that have experienced rapid immigration in the past few decades. Secular declines in hip fracture rates have been noted in the past decade primarily in developed countries, but hip fracture rates seem to be increasing in Mexico and China.

The magnitude of the international variability in hip fracture incidence is striking but, as yet, unexplained. The aetiology of hip fractures is complex, and the large variability in hip fracture rates worldwide probably reflects a multitude of genetic, lifestyle, medical, socioeconomic and environmental factors. Various country indicators of socioeconomic status, development, health and urbanization seem to be positively correlated with age-standardized hip fracture rates, such that high rates are observed in rich, developed countries. To some degree, this correlation could reflect inaccurate ascertainment of hip fracture rates in poor countries, but it might also suggest that lifestyles in developed countries contribute to high hip fracture rates. Further understanding of possible contributors to this variability in fracture rates could make substantial contributions to our understanding of the aetiology of osteoporotic fractures, and provide new avenues for prevention.

Review criteria

MEDLINE was searched for English-language full-text articles with the following terms separately or in combination: "fracture", "incidence" and the specific country of interest. A combined search with the three completed concept searches was used to identify the final search results. Articles published from November 1988 up to 15 September 2013 were included. Studies reported in a compendium of country-specific reports from the International Osteoporosis Foundation were also searched.

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Author contributions

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