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Secular Trends in Hip Fractures Worldwide: Opposing Trends East Versus West

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ABSTRACT

Despite wide variations in hip rates fractures worldwide, reasons for such differences are not clear. Furthermore, secular trends in the age-specific hip fracture rates are changing the world map of this devastating disease, with the highest rise projected to occur in developing countries. The aim of our investigation is to systematically characterize secular trends in hip fractures worldwide, examine new data for various ethnic groups in the United States, evidence for divergent temporal patterns, and investigate potential contributing factors for the observed change in their epidemiology. All studies retrieved through a complex Medline Ovid search between 1966 and 2013 were examined. For each selected study, we calculated the percent annual change in age-standardized hip fracture rates de-novo. Although occurring at different time points, trend breaks in hip fracture incidence occurred in most Western countries and Oceania. After a steep rise in age-adjusted rates in these regions, a decrease became evident sometimes between the mid-seventies and nineties, depending on the country. Conversely, the data is scarce in Asia and South America, with evidence for a continuous rise in hip fracture rates, with the exception of Hong-Kong and Taiwan that seem to follow Western trends. The etiologies of these secular patterns in both the developed and the developing countries have not been fully elucidated, but the impact of urbanization is at least one plausible explanation. Data presented here show close parallels between rising rates of urbanization and hip fractures across disparate geographic locations and cultures. Once the proportion of the urban population stabilized, hip fracture rates also stabilize or begin to decrease perhaps due to the influence of other factors such as birth cohort effects, changes in bone mineral density and BMI, osteoporosis medication use and/or lifestyle interventions such as smoking cessation, improvement in nutritional status and fall prevention. © 2014 American Society for Bone and Mineral Research.

KEY WORDS: SECULAR TRENDS; HIP FRACTURE RATES; AGE-STANDARDIZED; URBANIZATION; BIRTH COHORT EFFECT

Introduction

Hip fractures are the most devastating osteoporotic fracture at both the personal and societal level. Thirty to fifty percent of hip fracture patients lose functional independence, 20% to 40% die within the first year, and of those who survive, 10% may ultimately sustain a hip fracture of the contralateral hip.[1–4] With aging populations and an increase in age-specific hip fracture rates in many developing countries,[5] the global human, social, and economic costs of osteoporosis is rising, most dramatically in the most populous areas of the world http://documents.worldbank.org/curated/en/2008/01/13198371/population-aging-economic-growth. For example, the incidence of hip fracture has already risen twofold to threefold in most Asian countries during the past 30 years, and by 2050 more than 50% of all osteoporotic fractures will occur in Asia.[6,7] Similarly, the number of hip fractures is projected to double and even quadruple in some countries in the Middle East (http://www.iofbonehealth.org/regional-audit).

The aim of our study is to conduct a detailed synthesis of the literature on secular trends in hip fractures and to examine new evidence of strikingly divergent temporal patterns in hip fracture incidence worldwide, including new data from Southern Europe, the Middle East, Asia, and South America, in addition to data on ethnic differences in secular trends in the United States. Furthermore, we explore the intriguing possibility of urbanization as a contributing factor to the rise in hip fracture rates in both the West and the East.[8] Insight into such changes and their underpinnings provide essential information needed to design effective strategies to address this growing health threat worldwide.

Materials and Methods

Literature search and selection criteria

A Medline OVID search covering the period between January 1, 1966, to February 29, 2012, and updated for the purpose of this publication until October 31, 2013, was designed and initially

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conducted to evaluate the geographic variability in hip fractures worldwide.[9] The search was limited to the English language and to human adults aged 19 years and above. Two Boolean models were created: the first model consisted of the following concepts and their related terms in the Medical Subject Headings (MESH; NCBI; http://www.ncbi.nlm.nih.gov/mesh): hip fracture, incidence, and part X of the world with each concept searched singly, then merged through the AND term; where part X of the world represents either the continent subdivided into Northern, Southern, Eastern, and Western parts, or a specific region (Scandinavia and the Middle East) or a specific country (USA, Canada, and Australia); the second model also consisted of three concepts: osteoporotic fracture, incidence, and part X of the world; and the same search strategy was applied. The first model retrieved 3734 publications and the second model retrieved 2826 publications. All articles were scanned by title to select relevant titles; common titles retrieved from the two models were then removed. During this process, the articles discussing incidence of fractures and secular trends were triaged for further evaluation and selected as detailed below. Other relevant articles were selected from the reference list of the evaluated articles, the authors' libraries, and major scientific meetings. Selection criteria were as follows: (1) articles published in the English language; (2) studies including hip fracture rates at different time points over a defined more than 1-year period in a specific population; (3) studies in which rates were standardized to an internal reference population representative of the population studied—a few studies standardizing to an external populations or not providing standardized rates are discussed in the text but are not included in the figures; and (4) same database and method of data collection for hip fractures used at the beginning and at the end of the follow-up.

Calculation of annual percentage change in fracture rates

For each study selected, the percent annual change in age-standardized hip fracture rates for men, women, and both genders combined was calculated de novo between two time points by subtracting the age-standardized rate of hip fractures of the first study year from that of the last study year, then dividing the result by the first rate, and then by the number of years between the two time points. The result is expressed in % change/year.

Results

Sixty articles were included in the final analysis, representing countries from North and South America, Europe, Oceania, and Asia. Secular trends in age-standardized hip fracture rates by gender are illustrated in Fig. 1*A*, *B*. Additional data from countries for which age-standardized rates could not be calculated are summarized in Table 1.

North America

The earliest studies exploring temporal trends in hip fracture incidence with the longest follow-up were conducted in Rochester, MN, USA,[10–12] a predominantly white community with self-contained medical care. From 1928 to 1972,[11] the annual age-adjusted rates rose rapidly in women and started to fall slowly thereafter, whereas rates in men rose more steadily and began a downturn after 1980. For both genders combined, age-adjusted rates increased by 3.8%/year from 1928 until 1972, then showed a trend toward a decrease of 0.4%/year from 1972 until 1992 (Fig. 1*A*, *B*). Extension of follow-up in the same region[11] from 1980 until 2006 showed a continued decline in age-adjusted rates of first-ever hip fracture by 1.4%/year in women and stabilization of rates in men. Rates of all hip fractures, including recurrent ones, also declined by 1.4%/year in women and 0.4%/year in men. An important finding in this follow-up, although not reaching statistical significance, was the lower relative risk of recurrent hip fracture in those whose first-ever hip fracture occurred in 2000 to 2006 compared to earlier decades after adjusting for the expected risk of fracture, despite the lack of a systemic change in osteoporosis management among hip fracture patients. A more recent nationwide representative study[13] of age-adjusted hip fracture rates in a 20% sample of patients aged 65 years and older enrolled in Medicare between 1985 and 2005, including recurrent hip fractures occurring more than 180 days after the first one, demonstrated annual increases of 0.9% and 1.6% in women and men, respectively (changes were most pronounced in those aged 75 years and older), between 1985 and 1995, followed by a remarkable decline of 2.4%/year in women and 1.9%/year in men between 1995 and 2005.

In California, the state with the largest proportion of Hispanic residents in the United States, a study using a hospital discharge database in patients 55 years and older identified discordant trends in hip fracture rates among different ethnic groups between 1983 and 2000.[14] Although age-adjusted rates decreased by 0.6% per year among non-Hispanic white women, the rates in Hispanic women increased by 4.9% per year and did not change in black or Asian women. Similarly, in men, rates increased by 4.2% per year among Hispanics and remained almost the same in other ethnic groups. In a more recent cohort study examining hip fracture rates between 2000 and 2009, using a 5% random sample from the Medicare national database, Wright and colleagues[15] showed continued declines in hip fracture incidence in white women and men, whereas black and Asian beneficiaries experienced nonsignificant declines and the rates of Hispanic women and men changed minimally over time. As a result, ethnic minorities comprise an increasing proportion of hip fracture cases in the United States, with Hispanics increasing from 3% of cases in 1983 to 7% in 2000, and Asians from 2% in 1983 to 4% in 2000.[15]

In Canada, a recent large nationwide study analyzing data from the Hospital Morbidity Database over 21 years (1985 to 2005)[16] showed continuously decreasing rates of age-adjusted hip fracture rates in men and women. Furthermore, regression analysis identified a significant change in the slope around 1996, with a decrease of 1.2% per year from 1985 to 1996 and 2.4% per year after 1996. Regional studies from Ontario and Quebec showed a similar trend in hip fracture rates as the national study, showing a plateau in the age-adjusted rates through the 1980s, followed by a progressive acceleration in the decline after the mid-1990s.[17–20] A more recent large regional study from the province of Manitoba examined fractures in men and women aged 50 years and above between 1986 and 2006,[21] demonstrated annual declines in age-adjusted hip fracture rates of 1% in women and 0.7% in men, with an acceleration of the rate of decline after 1996 in both men and women comparable to the trend reported in the national and other regional studies.

In Mexico,[22] national data spanning the period between 2000 and 2006 showed an increase in age-specific hip fracture rates in men and women, an effect that was mainly observed at older ages; however, age-standardized rates were not provided.

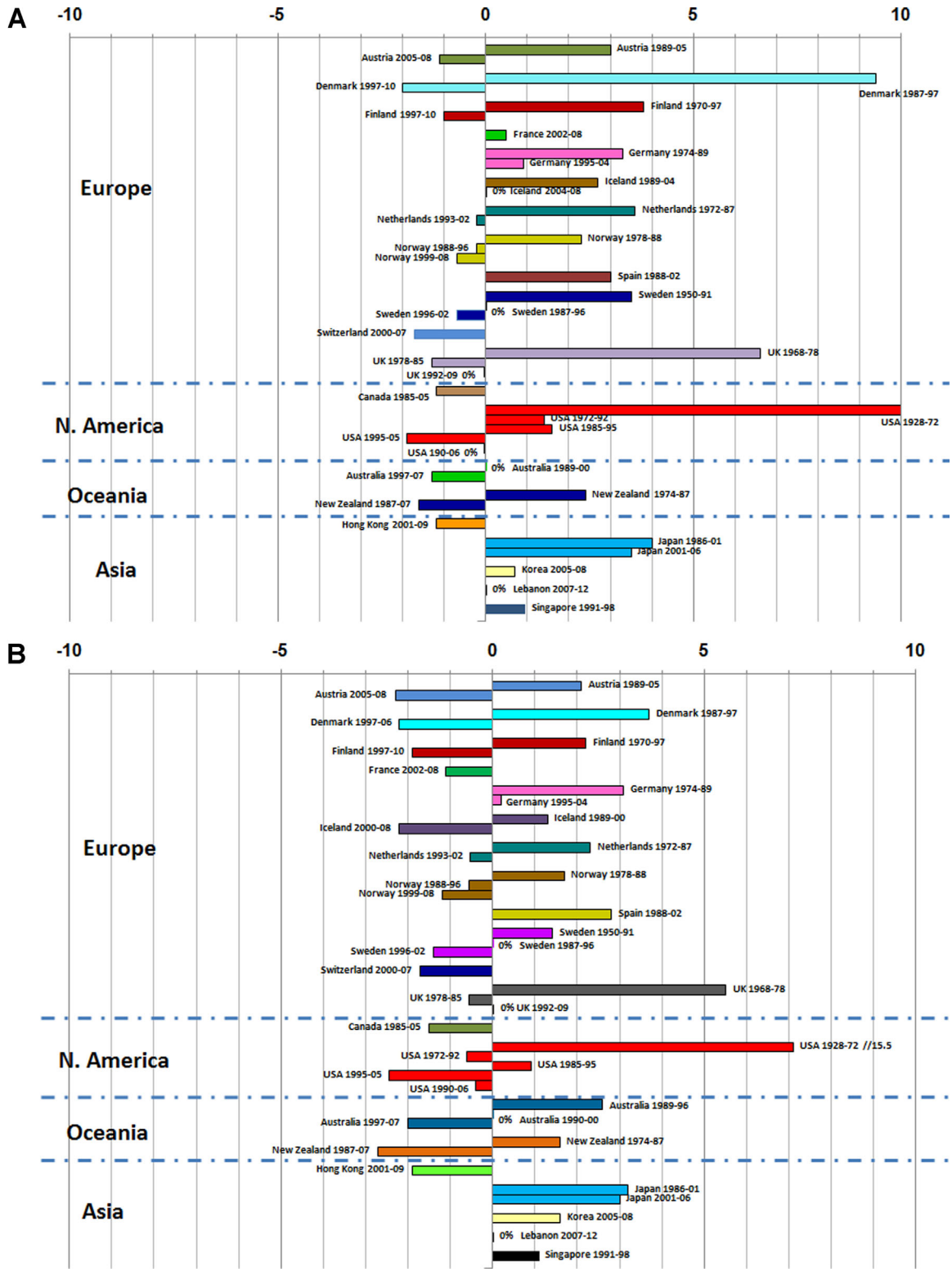

Fig. 1. Secular trend in hip fractures by continent in men (*A*) and women (*B*). For country-study selected, the percent annual change in age-standardized hip fracture rates for men and women is calculated between two time points by subtracting the age-standardized hip fracture rate of the first study year from that of the last study-year, then dividing the result by the first rate, and then by the number of years between the two time points. The result is expressed in percent change/year.

Table 1. Percent Annual Change in Age-Standardized Hip Fracture Rates in Women and Men Worldwide

Region	Country	Source[a]	Period	Catchment	Annual change, women (%)[b]	Annual change, men (%)[b]	Annual change, both genders (%)
North America	United States	Melton and colleagues (1998)[11]	1928–1972	R(Rochester)	+ 7.1	+15.5	+8.2
		Melton and colleagues (1998)[11]	1972–1992	R(Rochester)	–0.6	+1.4	–0.2
		Melton and colleagues (2009)[12]	1980–2006	R(Rochester)	–1.4	–0.06	
		Brauer and colleagues (2009)[13]	1985–1995	N	+0.9	+1.6	
		Brauer and colleagues (2009)[13]	1995–2005	N	–2.45	–1.9	
	Canada	Leslie and colleagues (2009)[16]	1985–2005	N	–1.5	–1.2	–1.4
		Leslie and colleagues (2011)[21]	1986–2006	R(Manitoba)	–1	–0.5	
		Vanasse and colleagues (2012)[20]	1993–2004	R	–1.1	–0.83	
South America	Ecuador	Orces (2011)[23]	1999–2008	N	+3.8	+2.6	+3.4
Northern Europe	Denmark	Giversen (2006)[24]	1987–1997	R(Viborg)	+3.7	+9.4	+5.1
		Abrahamsen and Vestergaard (2010)[25]	1997–2006	N	–2.2	–2	
		Rosengren and colleagues (2013)[26]	1993–2010	N			–1.2
	Finland	Korhonen and colleagues (2013)[27]	1970–1997	N	+2.2	+3.8	
		Korhonen and colleagues (2013)[27]	1997–2010	N	–1.9	–1	
	Iceland	Siggeirsdottir and colleagues (2014)[35]	1989–2000	N	+1.3		
		Siggeirsdottir and colleagues (2014)[35]	2000–2008	N	–2.2		
		Siggeirsdottir and colleagues (2014)[35]	1989–2004	N		+2.7	
		Siggeirsdottir and colleagues (2014)[35]	2004–2008	N		0	
	Norway	Lofthus and colleagues (2001)[28]	1978–1988	R(Oslo)	+1.7	+2.3	
		Lofthus and colleagues (2001)[28]	1988–1996	R(Oslo)	–0.56	–0.22	
		Emaus and colleagues (2011)[29]	1994–2008	R(Harstad)	+0.54	+2.8	
		Omsland and colleagues (2012)[30]	1999–2008	N	–1.2	–0.7	
	Sweden	Gullberg and colleagues (1993)[31]	1950–1991	R(Malmo)	+1.4	+3.5	–2.6
		Bergstrom and colleagues (2009)[33]	1993–2005	R(Umea)	–2.6	–0.85	
		Rosengren and colleagues (2012)[34]	1987–1996	N	0	0	
		Rosengren and colleagues (2012)[34]	1996–2002	N	–1.4	–0.7	
Central Europe	Germany	Wildner and colleagues (1999)[36]	1974–1989	R(East G)	+3.1	+3.3	
		Icks and colleagues (2008)[37]	1995–2004	N	+0.2	+0.9	+0.4
	Netherlands	Boereboom and colleagues (1992)[38]	1972–1987	N	+2.3	+3.6	
		Goettsch and colleagues (2007)[39]	1993–2002	N	–0.52	–0.21	–0.37
	United Kingdom	Spector and colleagues (1990)[40]	1968–1978	N	+5.5	+6.6	
		Spector and colleagues (1990)[40]	1978–1985	N	–0.55	–1.3	
		Balasegaram and colleagues (2001)[41]	1992–1999	N	0	0	
		Wu and colleagues (2011)[42]	1998–2009	N			0
	Ireland	McGowan and colleagues (2013)[43]	2000–2009	N	–1	0	
	Austria	Dimai and colleagues (2011)[44]	1989–2005	N	+2.1	+3	+2.2
		Dimai and colleagues (2011)[44]	2005–2008	N	–2.3	–1.1	–2
	France	Maravic and colleagues (2011)[45]	2002–2008	N	–1.1	+0.5	
	Switzerland	Lippuner and colleagues (2011)[46]	2000–2007	N	–1.7	–1.7	
Southern Europe	Spain	Hernandez and colleagues (2006)[47]	1988–2002	R(Cantabria)	+2.8	+3	+2.8
		Arias and colleagues (2013)[48]	2002–2008	N	–0.3	+0.3	–0.3
Oceania	Australia	Chipchase and colleagues (2000)[53]	1989–1996	R(South)	+2.6	0	
		Boufous and colleagues (2004)[54]	1990–2000	R(NSW)	0	0	
		Crisp and colleagues (2012)[56]	1997–2007	N	–2	–1.3	
	New Zealand	Langley and colleagues (2011)[57]	1974–1987	N	+1.6	+2.4	
		Langley and colleagues (2011)[57]	1987–2007	N	–2.7	–1.6	
South East Asia	Japan	Hagino and colleagues (2005)[58]	1986–2001	R(Tottori)	+3.2	+4	
		Hagino and colleagues (2009)[59]	2001–2006	R(Tottori)	+3	+3.5	
	South Korea	Lim and colleagues (2008)[63]	2001–2004	N	+1.2	–3.9	
		Yoon and colleagues (2011)[64] [c]	2005–2008	N	+1.6	+0.7	
	China	Xia and colleagues (2012)[8] [c]	2002–2006	R(Beijing)	+14.4	+12.3	
	Hong Kong	Lau (1989)[65]	1965–1985	N	+6.5	+4.4	
		Chau and colleagues (2013)[69]	2001–2009	N	–1.9	–1.2	
	Singapore	Koh and colleagues (2001)[60]	1991–1998	N	+1.1	+0.95	
	Taiwan	Chan and colleagues (2013)[70]	1999–2010	N			–2.5
Middle East	Lebanon	Sibai and colleagues (2011)[71] [c]	2007–2008	N	0	0	
		Ahmadieh, El-Hajj Fuleihan, unpublished data[c]	2009–2012				

R = regional study; N = national study; NSW = New South Wales.

[a]All the studies using age-standardized rates, whether to an internal or to an external population were included in the table.

[b]For country-study selected, the percent annual change in age-standardized hip fracture rates for men and women is calculated between two time points by subtracting the age-standardized hip fracture rate of the first study year from that of the last study-year, then dividing the result by the first rate, and then by the number of years between the two time points. The result is expressed in % change/year.

[c]All studies using age-standardized rates to an external population.

South America

Studies on hip fracture trends in South America are lacking except for Ecuador. Nationwide data in Ecuador was collected prospectively from the national surveillance system between 1999 and 2008.[23] This data demonstrated dramatic increases in the annual age-standardized hip fracture incidence rates by 3.8%/year in women and 2.6%/year in men.

Europe

Secular trend analysis is available for many countries in Scandinavia, Central Europe, and Southern Europe, with the most robust data stemming from Scandinavian countries where national health care registries were established toward the latter half of the last century.

Scandinavia

Scandinavian countries report some of the highest rates of hip fractures worldwide, with evidence for changing temporal patterns in age-adjusted incidence rates available for Denmark, Finland, Norway, Sweden, and Iceland.

A register-based study of patients aged 50 and above in Viborg county, Denmark,[24] documented a 56% increase in the age-adjusted incidence rates of first hip fracture for both genders between 1987 and 1997, an increase that was more pronounced in men (10.4%/year) than in women (4.1%/year). When secular trends were examined from 1980 to 2010 in nationwide Danish register-based studies,[25,26] the age-standardized rate of hip fractures increased by 2.8%/year between 1980 and 1993 in both genders combined and then decreased by 1.2% per year after 1993.

In Finland, nationwide data on hip fractures available from the Finnish National Hospital Discharge Register showed a considerable rise in age-adjusted hip fracture rates among those 50 years and older between 1970 and 1997 in both genders, averaging 3.8%/year in men and 2.2%/year in women.[27] However, consistent decreases in age-standardized rates became evident starting in 1997 with 1%/year and 1.9%/year declines in men and women, respectively, between 1997 and 2010, a trend that is very similar to that observed in Denmark.

In Oslo, Norway, the decline in age-adjusted hip fracture rates started somewhat earlier than in Denmark and Finland. Comparing rates in 1978/79, 1988/89, and 1996/1997,[28] it was shown that rates increased in men (2.3%/year) and women (1.7%/year) between 1978 and 1988, with a decreasing trend between 1988 and 1996. On the other hand, a recent study from Harstad, Northern Norway,[29] encompassing the years from 1994 to 2008 showed significantly lower age-adjusted rates than in Oslo, but in contrast a trend toward increasing rates over the study period, more significant in men (2.8%/year) than in women (0.5%/year). The different trends within the same country highlight both regional variations in hip fracture incidence and the possibility of regional differences in secular trends within the same country. However, national data from the hospitals' patient administrative systems[30] recently showed continuously decreasing rates overall between 1999 and 2008 (0.7%/year in men and 1.2%/year in women) in line with the data from Oslo.

In Sweden, the trend break appears to have occurred in the early to mid-1990s based on data reported from two regions, Malmö and Umea, and nationwide. In Malmö, data collected in the Department of Diagnostic Radiology[31] showed an exponential increase in age-standardized hip fractures rates of 1.4%/year in women and 3.5%/year in men between 1950 and 1991, with a significant increase across all age groups in men, but only at older ages in women: 70 to79 years and over 80 years. A more recent study from Malmö using data from the Department of Diagnostic Radiology and the Department of Orthopedics in Malmo University Hospital covering 97% of trauma patients in Malmo, suggests stabilization of age-standardized rates of hip fractures between 1990 and 2001[32] with a trend break in fracture rates occurring in the early 1990s. Other regional data coming from Umeå, Sweden,[33] demonstrated a decline in age-adjusted rates between 1993 and 2005 of 2.6%/year in women and 0.85%/year in men. A recent analysis of national data[34] from the register of the Swedish National Board of Health including all hospital discharges in Sweden shows stable age-standardized rates between 1987 and 1996, which then started to decline at a rate of 0.7%/year in men and 1.4%/year in women between 1996 and 2002.

In Iceland, a recent study[35] showed that the trend break in this country occurred at a later point, in the early years of the 21st century (Fig. 1*A*, *B*; Table 1).

In summary, data from Scandinavian countries indicate increasing incidence in age-adjusted rates of hip fracture until the 1990s, followed by decreasing rates occurring somewhat later than in North America, beginning in the early 1990s in Norway and Sweden, and in the mid-late 1990s in Denmark and Finland.

Central Europe

Available studies from Central Europe again show a pattern of rising rates followed by recent stabilization in age-standardized hip fracture rates in Germany, the Netherlands, and the United Kingdom, and decreases in rates in Austria, France, and Switzerland. An initial steep increase in age-adjusted hip fracture rates in East Germany was reported between 1974 and 1989 in both genders for patients aged 60 years and above, 3.3%/year in men and 3.1%/year in women.[36] However, a recent population-based study[37] analyzing trends between 1995 and 2004 suggests a slowing of the annual increase in the fracture rate to 1.4%/year for both genders combined. The same study reported a smaller increase of 0.3%/year for both genders combined in West Germany between 1995 and 2004, although the total age-standardized incidence to the total German population in 2000 was still higher in West Germany than in East Germany.

A similar picture is seen in the Netherlands, where nationwide data show a linear increase in age-adjusted hip fracture rates in both men (3.6%/year) and women (2.3%/year) aged 50 and above between 1972 and 1987.[38] Subsequently, nationwide data from 1993 to 2002[39] showed a slow decline of 0.2%/year in men and 0.5%/year in women since 1993. The same study analyzed the incidence of osteoporosis during the same period using the PHARMO database that includes pharmacy dispensing records linked to hospital discharge records of 40 population-defined areas in the Netherlands (osteoporosis proxy) and showed that the incidence of osteoporosis decreased by 19% during the same period.

In the United Kingdom, age-adjusted hip fracture rates increased steadily between 1968 and 1978 in both men and women, by 6.6%/year and 5.5%/year, respectively, and subsequently decreased by 1.3%/year in men and 0.55%/year in women between 1978 and 1985.[40] In a trend analysis using national data from the Department of Health information,[41]

age-standardized rates remained almost unchanged between 1992 and 1999. Using the same database from 1998 to 2009,[42] age-adjusted incidence rates also remained unchanged overall for both genders combined, despite fluctuations between 1998 and 2003. These data could not be included in the summary figures because age-standardized rates were not provided separately for each gender, but they are illustrated in Table 1.

Available trend analysis from Ireland is more recent and spans the period between 2000 and 2009, showing stable age-standardized rates in men and a 1% annual decrease in women.[43]

Hip fracture trends in Austria were examined for the entire Austrian population aged 50 years and above between 1989 and 2008.[44] In women, the age-standardized incidence increased until 1999, dipped slightly in 2000, remained fairly stable from 2001 until 2005, and then started to decrease until 2008. In men, the incidence rate increased at a steady pace until 2006, and declined thereafter. Annual changes calculated for the two periods 1989 to 2005 and 2005 to 2008 are shown in Fig. 1*A*, *B*.

The recent nationwide data from France,[45] reporting hip fracture rates in patients aged 40 years and above between 2002 and 2008 showed a significant decrease in age-specific hip fracture rates, both in men and women for the age groups 60 to 74, 75 to 84, and above 85 years (Table 1). However, annual changes to illustrate secular trends could not be calculated because age-standardized rates were not provided.

Over almost the same period (2000 to 2007) as that studied in France, nationwide data from the Swiss Federal Statistical Office also reported a significant linear trend of decreasing age-adjusted rates of hip fractures of 1.7%/year in men and women aged 45 years and above.[46] The largest decrease was observed in the 65 to 74 years age group in both genders.

Southern Europe

Data from Southern Europe is scarce. Available data from Cantabria in Northern Spain, in 1988 and 2002, shows a significant increase in the rates of hip fractures of 3%/year and 2.8%/year in men and women, respectively between these two data points.[47] More recent national data showed stable rates in men and women between 2002 and 2008.[48]

A recent trend study from Greece,[49] collecting data by a questionnaire sent to all public and private orthopedic departments for the years 1997, 2002, and 2007, compared the age-adjusted hip fracture rates to those reported by a previous study[50] for the years 1977, 1982, 1987, and 1992. It showed that rates increased significantly between 1977 and 2002 (3.3%/year in men and 4.9%/year in women) but later stabilized in men and decreased in women by 1.5%/year between 2002 and 2007. The accuracy of the data was difficult to assess because they were collected by questionnaire without using the International Classification of Diseases (ICD) code to define fractures, and incidence rates were limited to selected years rather than the entire time period. Comparison of two incidence studies from Turkey suggests a substantial increase in hip fracture rates over a 20-year period. The MEDOS study[51] conducted in 1988 to 1989, reports very low crude rates in men (24/100,000 to 62/100,000) and women (28/100,000 to 34/100,000) over 50 years of age. Twenty years later, the FRACTURK study[52] conducted in 12 Turkish regions, many overlapping those of the MEDOS study, in addition to two hospitals, reported a several-fold increase in both genders, with crude rates of 119/100,000 in men and 227/100,000 in women. The increase was observed in all age groups but was most striking in women above the age of 70 years.

Oceania

Trend analyses in Australia are based on regional studies and one recent national study. A study conducted in South Australia between 1989 to 1996,[53] in patients over age 50 years, found no significant temporal changes in age-standardized fracture rates in men or women. Data from New South Wales between 1990 and 2000,[54] showed that age-standardized rates remained stable. The Dubbo osteoporosis epidemiology study[55] also showed no significant change in the age-specific hip fracture incidence rates between 1989 and 2000 in patients aged 65 years and above; however, no age-standardized rates were provided to enable calculation of annual change. Overall, this regional data indicates stable age-adjusted hip fracture incidence rates in Australia from the late 1980s until 2000. More recent nationwide[56] data from all public and private hospitals in Australia, through the National Hospital Morbidity Database, has shown decreasing age-adjusted hip fracture rates in both genders (1.3%/year in men and 2%/year in women) between 1997 and 2007.

National data from New Zealand,[57] between 1974 and 2007 indicates trends similar to those observed in North America and Scandinavia. Age-adjusted hip fracture incidence rates in men over age 50 years rose by 2.4%/year between 1974 and 1987, then decreased by 1.6%/year between 1987 and 2007, but remained at 1.2 times the rate observed in 1974. In women, age-adjusted rates increased by 1.6%/year between 1974 to peak in 1987 and declined thereafter by 2.7%/year until 2007, when rates became 0.86 times the 1974 rate.

South-East Asia

Temporal trends in hip fractures in Asia differ markedly from those observed in Western countries and show an overall continuous increase except in highly urbanized areas such as Hong Kong and Taiwan.

In Japan, the most detailed analyses of temporal trends have been conducted in Tottori prefecture, in southern Japan. A comparison of hip fracture rates for three time-periods, 1986 to 1988, 1992 to 1994, and 1998 to 2001,[58] showed a significant increase with time for both genders, 4%/year in men and 3.2%/year in women. A follow-up study[59] for the years 2004 to 2006 documented a continued increasing age-adjusted hip fracture rate of 3.5%/year in men and by 3%/year in women compared to 2001.

Nationwide data from Singapore[60] collected on residents aged 50 years and above showed an increase in age-adjusted hip fracture rates of 0.9%/year in men and 1.1%/year in women between 1991 and 1998. Comparison of rates with those of the 1960s,[61] despite a different methodology, suggests a dramatic increase in hip fracture incidence rates over the past 40 years with rates age-standardized to the 1985 United States population, which were 1.5 and 5.5 times higher in the 1995 to 1998 period than those of the 1955 to 1962 period in men and women, respectively.[62] The rapid increase in fracture rates among women was seen only in the Chinese and Malay ethnic groups, whereas the rates among Indians decreased from the high rates seen in the 1960s.

A recent trend analysis in South Korea spanned the period from 2001 to 2008. The first national study[63] covering 97% of the total population examined data from the Health Insurance

Review Agency from 2001 to 2004, in patients aged 50 years and above, showed an increase in the age-adjusted hip fracture rates in women of 1.2%/year in contrast to a decrease in men of 3.9%/year. However, the decreasing trend in men was not confirmed in the second national study covering the period from 2005 to 2008,[64] using the same database, which used a more stringent definition of hip fracture. This study showed an increasing trend in both genders, of 0.7%/year in men and 1.6%/year in women (Table 1). Because rates were calculated standardized to an external population in the second study, Korea is not included in Fig. 1*A*, *B*, but it is included in Table 1.

In China, a dramatic increase in hip fractures rates was recently reported in Beijing residents aged 50 years and over.[8] Comparing hip fracture data from 1990 to 1992 to those in 2002 to 2006, age-adjusted rates increased 1.6-fold in men and 2.8-fold in women between the two periods. In addition, a marked increase in hip fracture rates was also noted from 2002 to 2006 with an annual change of 12.3%/year and 14.4%/year in men and women, respectively (Table 1). These findings were not included in the figures because rates were age-standardized to the 2004 U.S. Census, as opposed to the Chinese population at large.

Temporal trends in Hong Kong were also examined by comparing rates provided by different studies at different time points. Lau and colleagues[65] compared age-standardized rates in 1965 to 1967[66] to rates in 1985 and showed a rise of 4.4%/year in men and of 6.5%/year in women. In a similar study, the same author demonstrated decreasing age-specific rates from 1985 to 1995 except in women aged 70 to 79 and 80+ years and in men aged 60 to 69 years.[67] However, rates were not age-standardized to allow calculation of yearly changes, and evaluation of trends over time. More recently, two nationwide studies,[68,69] using the same database, examined fracture rates for the periods between 1995 and 2004 and 2001 and 2009, respectively, and showed that age-adjusted rates declined by 1.2%/year in men and by 1.9%/year in women between 2001 and 2009.[69]

Recent national data from Taiwan[70] also shows a decreasing trend of hip fractures in both genders combined (2.5%/year) between 1999 and 2010, paralleling the decrease observed in Hong Kong.

In summary, the published information on gender-specific incidence of hip fractures in Hong Kong show that hip fracture rates rose rapidly in Hong Kong from 1966 to 1985 in men and up to 1995 in women then started to decline in both genders, a decline that was also documented in Taiwan between 1999 and 2010. This trend is consistent with that of Western countries, and is in sharp contrast to the consistently rising rates in other Asian countries.

Middle East

The only data on hip fracture trends in the Middle East comes from representative data on hip fracture rates from the Lebanese National Hip Fracture registry, for years 2007 to 2012 in men and women above 50 years of age[71] (Ahmadieh H, El-Hajj Fuleihan G, unpublished data). It showed no change in age-standardized rates in either gender.

Discussion

Analysis of secular trends in age-adjusted hip fracture rates worldwide shows differences in the trends and their timing between countries and continents. In the United States, Canada, Northern Europe, Oceania, Hong Kong, and Taiwan, the earliest studies demonstrated high or rising age-adjusted rates of hip fractures, which then reached a plateau or started to decline, albeit at somewhat different time points. The earliest decreases were noted in the United Kingdom starting in the late 1970s and in North America starting in the mid-1980s, followed by Scandinavia where rates started to decline in the early 1990s for Norway and Sweden, and the late 1990s for Denmark and Finland. On the other hand, continuously rising rates have been reported from Southern Europe, South America, and many parts of Asia.

Data regarding secular trends in the incidence of hip fractures in papers published until 2010 was reviewed previously by Cooper and colleagues.[5] Since that time, data on secular trends has become available for the first time for Ecuador,[23] Iceland,[35] Taiwan,[70] and Lebanon[71] (Ahmadieh H, El-Hajj Fuleihan G, unpublished data); new nationwide studies are available from Sweden,[34] Norway,[30] Turkey,[52] and Australia[56]; and updated data are available from Finland,[27] Denmark,[26] Greece,[49] Korea,[63,64] China (Beijing),[8] and Hong Kong,[69] which are all included in our analyses. In addition, we have included data on secular trends in different ethnic groups in the United States.[15] Morin and colleagues[72] recently performed a brief update on the information presented by Cooper and colleagues,[5] and included some, but not all, of the countries we covered above, and did not cover the new studies in Asia.[60,62–64,70]

Our approach differs substantially from the two prior papers[5,72] in several aspects. Most importantly, we performed an extensive study exclusively focusing on hip fractures from 1966 until November 2013, and implemented a de novo calculation for deriving estimates for secular trends for all countries of interest based on the original data published, and clearly separated data evaluation by gender. In some instances, we also included additional time segments within the same study period to better define temporal changes in fracture rates. For example, in Austria,[44] we showed an increase in rates from 1989 until 2000 followed by a stabilization until 2005, and a decrease in rates from 2005 until 2008. In Germany, this new data[35,36] revealed a recent slowing in the rate of increase (3.1%/year in women from 1974 to 1989 as compared to 0.2%/year from 1995 to 2004).

Our study also led to some interesting new findings. For example, although many regions of Asia are experiencing sustained increases in fracture rates, rates in two highly developed areas, Hong Kong and Taiwan, are declining, similar to those of Western countries. Additionally, in most countries, with the exception of France, Austria, Spain, and Korea, hip fracture incidence follows the same trends in men and women. However, the rate of change is generally more pronounced in women, raising the possibility of gender-specific differences in the underlying causes for secular changes.

The etiology of rapid increases in hip fracture incidence documented until the 1970s in the United Kingdom, until the late 1980s and mid-late 1990s in the United States, Scandinavia, the Netherlands, Austria, and Hong Kong, and currently in most of Asia, Southern Europe, and Ecuador, remains unknown. It is well documented, however, that hip fracture rates are consistently found to be higher in urban than in rural areas,[73–75] which makes urbanization a plausible contributing factor to the rise in age-adjusted rates observed in developing countries. When examined together, the process of urbanization appears to parallel the increase in hip fracture rates in most regions,[76]

whereas stabilization in the proportion of the urban population is reflected in a cessation in the growth in age-standardized hip fracture rates. Nationwide data from North America show that the proportion of the urban population stabilized in 1990 at 78% in the United States and in 1970 at 75.7% in Canada[76,77]; the trend break in hip fractures occurred in the mid-1990s in the United States and by the mid-1980s fracture rates were declining in Canada. In most Asian countries, urbanization is still increasing in Japan, South Korea and Beijing providing an intriguing parallel to the continuous rise in hip fracture rates observed in this region. Hong Kong, on the other hand, was urbanizing rapidly at the same time fracture rates were climbing, becoming exclusively urban in 1990, at which time hip fracture rates stabilized and subsequently began to decline.

The mechanisms by which urbanization may impact hip fracture rates are not known, but may include decreased physical activity, an increase in hard surfaces, calcium and vitamin D deficiencies,[78] or other lifestyle factors.[79,80] Increased urbanization could also reflect an associated increase in prosperity and access to medical care, which could, theoretically, increase survival of the frailest elderly, as was recently proposed as a possible contributor to the increase in fracture rates among older Korean women.[81]

Of equal interest are the declining rates of fractures now being observed in North America, Europe, Hong Kong, and Taiwan. The increasing use of specific osteoporosis therapy has been proposed as a contributor to the decreasing rates of hip fractures in many countries. In the United States, a Medicare study by Brauer and colleagues[13] showed that the trend break in hip fracture incidence rates coincided with increasing use of bisphosphonates after 1996 and of selective estrogen receptor modulators after 1999. However, the low rate of medication use in this population makes it unlikely that this is the major explanation of the declining rates in the United States. In Canada,[13] decreasing hip fracture rates were evident before widespread use of bone density testing and the modern era of pharmacotherapy. In addition, the similar temporal patterns in fracture rates observed in men and women excludes a possible major contribution of postmenopausal hormone therapy to this decrease in incidence. Similarly, in Europe, the national study from Denmark,[25] analyzing trends in antiosteoporotic medication prescriptions in parallel to hip fracture incidence showed a sixfold lower prevalence of medication use in men despite a similar decrease in hip fracture rates in both genders. The authors calculated that, only 0.5% to 1.3% of prevented fractures in men and only 1.9% to 3.7% of prevented hip fractures in women could have been attributed to specific therapy.[25]

Other factors proposed to be playing a role in secular declines in hip fracture rates in North America and Europe are temporal changes in bone density and obesity. Looker and colleagues[82] demonstrated an increase in bone mineral density (BMD) in non-Hispanic U.S. white women, between the two periods 1988 to 1994 and 2005 to 2008. This may, in part, explain the decreasing trends in hip fracture incidence in this subgroup over time. Concurrently, data from the National Health Examination Survey (NHANES)[83] also documented increasing body size and weight over this time period, with the prevalence of overweight and obesity in U.S. adults rising from 56% in 1988 to 1994 to 64% in 1999 to 2000. Higher body weight has consistently been associated with greater BMD and lower rates of bone loss.[84] A recent meta-analysis of 12 prospective population-based cohorts[85] has also demonstrated a lower risk for hip fractures with higher body mass indexes (BMIs) (risk ratio per unit higher BMI of 0.93 [95% CI, 0.91 to 0.94], $p < 0.001$). These associations suggest that increasing BMI may be a contributor to the secular decrease in hip fracture rates observed in the United States and other Western countries. Leslie and colleagues,[86] however, recently demonstrated that improvements in BMD, rather than greater rates of obesity or osteoporosis treatment, was the best explanation of the linear decline in osteoporotic fractures in the Manitoba, Canada, database between 1996 and 2006. Whether the temporal increases in bone density observed in the United States and Canada are the result of intrauterine effects, greater bone mass accrual during early life, and/or to lower rates of adult bone loss is not known. This observation, however, suggests that birth cohort effects related to improvements in early-life risk factors, such as maternal and offspring nutrition, leading to a healthier aging population, may contribute to falling fracture rates. This hypothesis is supported by studies from Denmark,[87] Sweden,[34] Canada,[88] Korea,[89] and Portugal,[79] which found birth cohort effects on hip fracture incidence and BMD. For example, in Portugal, hip fracture risk was higher for those born during major economically or politically unstable periods, suggesting that conditions during fetal life or at birth may impact future risk for hip fractures. On the other hand, whereas Canadian men born prior to 1950 had significantly higher rates of hip fracture compared to those born after 1954, no significant birth cohort effect was observed in women to explain their temporal decline in hip fracture incidence.

Other factors such as the average increase in the number of reproductive years reported in women in the United States[80] and in Hong Kong[68] may have played a role in the trend breaks observed in women, but would not explain parallel changes in hip fractures in men. Other contributors, such as smoking cessation,[90] improvement in physical activity,[91] calcium intake and vitamin D status,[25,92] and fall prevention,[68,93,94] could have also influenced, to a limited extent, the hip fracture rates.

The possible influence of immigration on secular changes in fracture incidence should not be overlooked when evaluating fracture trends in developed countries. Lower fracture rates would be predicted if the composition of a country's population changed owing to an increasing proportion of immigrant populations who have a lower genetic risk of osteoporotic fractures, as has been documented for the peoples of Southern Europe, Africa, and Asia, compared to Scandinavia, the United Kingdom, the United States, and Canada.[95] In Sweden, for example, the percent of foreign-born permanent residents was 6.6% in 1970, 7.5% in 1980, 9.2% in 1990, 11.3% in 2000, and 12.2% in 2004.[96]

Some limitations to our study may be inherent to the search methodology and from the fact that only studies published in English were included. However, to the best of our assessment this investigation contains the most complete compendium on this topic to date. Other limitations are inherent to any other similar study and stem from the limited availability of trend studies and/or population-based studies. Indeed, although most countries had nationwide representative data, some countries such as Spain, Japan and China only had regional studies. In addition, trend data from Asia is very limited and no studies are available for countries such as India, Indonesia, and Pakistan, which rank among the most populous countries worldwide. Moreover, African countries completely lack secular trend data. Trend analysis in these regions is particularly important because they are expected to have the most striking increase in hip fracture rates in the future owing to demographic changes alone.[6,7] Another important limitation of trend analysis derives

from the accuracy of data collection. Some studies did not use the ICD code to define hip fractures.[29,31,58,59] In Beijing, China, for example, the data from public records was found to underestimate the rates of hip fractures in 1990 to 1992 by 75% largely because of miscoding of intertrochanteric fractures.[97] Adjustment of fracture rates for this underestimate was performed in the Beijing studies, but may not have been assessed and taken into account by other analyses. In other studies, data collection was not continuous over the study years, but rather reported hip fracture incidence for specific years at regular intervals.[8,28,50–52,58,59,67] Other studies had a short time span for secular trend analysis[8,22,60,63,64,71] (Ahmadieh H, El-Hajj Fuleihan G, unpublished data), which could mask the consistency in the rising or decreasing trends.

The importance of including secular trends in age-specific fracture rates in the prediction of the socioeconomic impact of fractures cannot be overstated. The annual number of hip fractures is projected to increase worldwide owing to aging of the world's population alone, with the majority of this increase expected in the developing countries. However, if a 1% secular increase in age-specific hip fracture rates for many regions of the world is additionally considered, a further 42% increase in frequency in hip fractures in 2025, and an 82% increase in 2050, are expected compared to the estimates based on demographic changes alone.[7] Furthermore, the projected number of hip fractures in 2050 will be five times higher when the 3%/year increase in age-adjusted hip fracture rates occurring outside North America and Northern Europe are considered.

For the individual patient, secular changes in fracture rates also affect fracture prediction and treatment decisions based on the country-specific Fracture Risk Assessment Tool (FRAX) calculator. The FRAX formula uses the country-specific (and, in the United States, ethnic-specific) hip fracture rates to calculate an individual's 10-year probability of fractures. The country-specific fracture rate must be revised to reflect secular trends for fracture prediction to be accurate. In the United States, the FRAX calculator was recently revised to reflect the observed decrease in age-specific fractures rates. As a result, hip fracture probability estimates dropped by as much as 40% compared to those produced by the older version of US-FRAX.[98] In developing countries with rapidly rising rates of fractures, and improved longevity, FRAX calculations will significantly underestimate fracture probability if not updated frequently.[99]

Conclusion

Evidence for secular changes in hip fracture rates is available for many countries and regions of the world, with rates currently declining in North America, Oceana, Northern Europe, Hong Kong, Taiwan, and in most of Central Europe, but with increasing rates of hip fractures in much of Asia, Southern Europe, and South America. Along with aging of the population, these secular changes in fracture incidence are expected to change the world map for hip fractures in the future, with the developing countries expected to lead the world in the annual number of hip fractures. This change will have many implications for both public and individual health management and will require fracture prevention programs in developing such as those in developed countries. In addition, further efforts to identify the factors related to increasing and decreasing incidences are needed in order to design public health strategies that could reduce fractures throughout the world.

Disclosures

All authors state that they have no conflicts of interest.

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