Original Article

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

Ghada Ballane, MD1, Jane A. Cauley, DrPH2, Marjorie M. Luckey3, and Ghada El-Hajj Fuleihan, MD, MPH1*

1 Calcium Metabolism and Osteoporosis Program, WHO Collaborating Center for Metabolic Bone Disorders, Division of Endocrinology and Metabolism - American University of Beirut Medical Center, Beirut, Lebanon.

2 Department of Epidemiology, Graduate School of Public Health, University of Pittsburgh, Pittsburgh, Pennsylvania, USA.

3 Barnabas Health Osteoporosis Center, Livingston, NJ, USA

*Corresponding author:
Ghada El-Hajj Fuleihan, MD, MPH
Calcium Metabolism and Osteoporosis Program,
American University of Beirut Medical Center
Bliss Street, Beirut 113-6044, Lebanon.
E-mail: gf01@aub.edu.lb
Tel: 961-1-737868
Fax: 961-1-745321 or 961-1-744464

†This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: [10.1002/jbmr.2218]

Initial Date Submitted December 9, 2013; Date Revision Submitted January 29, 2014; Date Final Disposition Set February 18, 2014

Journal of Bone and Mineral Research
© 2014 American Society for Bone and Mineral Research
DOI 10.1002/jbmr.2218
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 due to the influence of other factors such as birth cohort effects, changes in bone mineral density and body mass index, osteoporosis medication use and/or lifestyle interventions such as smoking cessation, improvement in nutritional status and fall prevention.

Keywords: AGING, Osteoporosis < DISEASES AND DISORDERS OF/RELATED TO BONE, General population studies < EPIDEMIOLOGY, Fracture risk assessment < PRACTICE/POLICY-RELATED ISSUES, STATISTICAL METHODS
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, twenty to forty percent die within the first year, and of those who survive, ten percent may ultimately sustain a hip fracture of the contra-lateral hip.\textsuperscript{1-4} With ageing populations and an increase in age-specific hip fracture rates in many developing countries,\textsuperscript{5} the global human, social, and economic costs of osteoporosis is rising, most dramatically in the most populous areas of the world (World Bank online data http://web.worldbank.org). For example, the incidence of hip fracture has already risen 2-3-fold in most Asian countries during the past 30 years, and by 2050 more than 50\% of all osteoporotic fractures will occur in Asia.\textsuperscript{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.\textsuperscript{8} Insight into such changes and their underpinnings provide essential information needed to design effective strategies to address this growing health threat worldwide.

MATERIAL AND METHODS

Literature search and selection criteria

A Medline OVID search covering the period between January 1\textsuperscript{st} 1966 to February 29\textsuperscript{th} 2012, and updated for the purpose of this publication until October 31\textsuperscript{st}, 2013 was designed and initially conducted to evaluate the geographic variability in hip fractures worldwide.\textsuperscript{9} Search was limited to English language and to human adults aged 19 and above. Two Boolean models were created: the first model consisted of the following concepts and their related
MESH* terms: hip fracture, incidence and part X of the world with each concept searched singly, then merged through the AND term; 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 3 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 2826 publications. All articles were scanned by title to select relevant titles; common titles retrieved from the 2 models were then removed. During this process, the ones 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, from the author's 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 one year period in a specific population 3) studies in which rates were standardized to an internal reference population representative of the population studied; few studies standardizing to an external populations or not providing standardized rates were discussed in the text but were not included in the figures 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 2 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 2 time points. The result is expressed in % change/year.

**RESULTS**

60 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 Figures 1 and 2.
Additional data from countries for which age-standardized rates could not be calculated are summarized in the Table.

**North America**

The earliest studies exploring temporal trends in hip fracture incidence with the longest follow-up were conducted in Rochester, Minnesota,\textsuperscript{10-12} a predominantly White community with self-contained medical care. From 1928 to 1972\textsuperscript{11}, the annual age-adjusted rates rose rapidly in women and started to fall slowly thereafter, while 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). Extension of follow-up in the same region\textsuperscript{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 2000-2006 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\textsuperscript{13} of age-adjusted hip fracture rates in a 20% sample of patients aged 65 and older enrolled in Medicare between 1985-2005, 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 that 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 US, a study utilizing 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\textsuperscript{14}, While 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 through 2009,
using a 5% random sample from the Medicare national database Wright et al showed continued declines in hip fracture incidence in White women and men, while Black and Asian beneficiaries experienced non-significant 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 USA, with Hispanics increasing from 3% of cases in 1983 to 7% in 2000, and Asians from 2% in 1983 to 4% in 2000.

In Canada, a recent large nationwide study analyzing data from the Hospital Morbidity Database over 21 years (1985-2005) 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 1980’s, followed by a progressive acceleration in the decline after the mid 1990’s. A more recent large regional study from the province of Manitoba examined fractures in men and women aged 50 and above between 1986 and 2006; 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.

**South America**

Studies on hip fracture trends in South America are lacking except for Ecuador and Mexico. Nationwide data in Ecuador was collected prospectively from the national surveillance system between 1999 and 2008. 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.

In Mexico, 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.
Europe

Secular trend analysis is available for many countries in Scandinavia, Central and Southern Europe, with the most robust data stemming from Scandinavian countries where national health care registries were established towards 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, documented a 56% increase in the age-adjusted incidence rates of first hip fracture for both genders between 1987 and 1997, an increase which was more pronounced in men (10.4%/year) than in women (4.1%/year). When secular trends were examined from 1980-2010 in nationwide Danish register-based studies, 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. 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, 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 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 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-1990’s based on data reported from 2 regions, Malmö and Umea, and nationwide. In Malmö, data collected in the Department of Diagnostic Radiology 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, 70-79 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 with a trend break in fracture rates occurring in the early 1990’s. Other regional data coming from Umeå, Sweden 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 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 showed that the trend break in this country, occurred at a later point, in the early years of the 21st century. (Figures 1 and 2 and table)

In summary, data from Scandinavian countries indicate increasing incidence in age-adjusted rates of hip fracture until the 1990’s followed by decreasing rates occurring somewhat later than in North America, beginning in the early 1990’s in Norway and Sweden, and in the mid-late 1990’s 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 UK, 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 and above, +3.3%/year in men and +3.1%/year in women. However, a recent population-based study 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. Subsequently, nationwide data from 1993 to 2002 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 forty population-defined areas in the Netherlands (osteoporosis proxy) and showed that the incidence of osteoporosis decreased by 19% during the same period.

In the UK, 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. In a trend analysis using national data from the Department of Health information, age-standardized rates remained almost unchanged between 1992 and 1999. Using the same database from 1998 to 2009, age-adjusted incidence rates also remained overall unchanged for both genders combined, despite fluctuations between 1998 and 2003. This data could not be included in the summary figures because age-standardized rates were not provided separately for each gender, but is illustrated in the Table.

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.
Hip fracture trends in Austria were examined for the entire Austrian population aged 50 and above between 1989 and 2008. 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 2 periods 1989-2005 and 2005-2008 are shown in the Figures.

The recent nationwide data from France reporting hip fracture rates in patients aged 40 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 60-74, 75-84 and above 85 years (Table). However, annual changes to illustrate secular trends could not be calculated because age-standardized rates were not provided.

Over almost the same period (2000-2007) 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 and above. The largest decrease was observed in the 65-74 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. More recent national data showed stable rates in men and women between 2002 and 2008.

A recent trend study from Greece 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 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 since they were
collected by questionnaire without using the 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\textsuperscript{51} conducted in 1988-1989 reports very low crude rates in men (24-62/100,000) and women (28-34/100,000) over 50 years of age. Twenty years later, the FRACTURK study\textsuperscript{52} conducted in 12 Turkish regions, many overlapping those of the MEDOS study, in addition to 2 hospitals, reported a several folds 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.

\textit{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,\textsuperscript{53} in patients over age 50, found no significant temporal changes in age-standardized fracture rates in men or women. Data from New South Wales between 1990 and 2000\textsuperscript{54} showed that age-standardized rates remained stable. The Dubbo osteoporosis epidemiology study\textsuperscript{55} also showed no significant change in the age-specific hip fracture incidence rates between 1989 and 2000 in patients aged 65 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 1980’s until 2000. More recent nationwide\textsuperscript{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\textsuperscript{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 rose by 2.4%/year between 1974 and 1987, then decreased by 1.6%/year between 1987 and 2007, but remained 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 3 time-periods, 1986-1988, 1992-1994, 1998-2001 showed a significant increase with time for both genders, +4%/year in men and +3.2%/year in women. A follow-up study for the years 2004-2006 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 collected on residents aged 50 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 1960’s, 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 US population which were 1.5 and 5.5 times higher in the 1995-1998 period than those of the 1955-1962 period in men and women respectively. The rapid increase in fracture rates among women was seen only in the Chinese and Malay ethnic groups while the rates among Indians decreased from the high rates seen in the 1960’s.

A recent trend analysis in South Korea spanned the period from 2001 to 2008. The first national study covering 97% of the total population examined data from the Health Insurance Review Agency from 2001-2004, in patients aged 50 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 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). Because rates were calculated standardized to an external population in the second study, Korea is not included in the Figures but is in the Table.
In China, a dramatic increase in hip fractures rates was recently reported in Beijing residents aged 50 and over. Comparing hip fracture data from 1990-1992 to those in 2002-2006, 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). These findings were not included in the figure because rates were age-standardized to the 2004 US 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 EM et al. compared age-standardized rates in 1965-1967 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 70-79 and 80+ and in men aged 60-69. However, rates were not age-standardized to allow calculation of yearly changes, and evaluation of trends over time. More recently, two nationwide studies utilizing the same database, examined fracture rates for the periods between 1995-2004 and 2001-2009 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.

Recent national data from Taiwan 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 comes in sharp contrast with 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. It showed no change in age-standardized rates in both genders.

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 USA, 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 UK starting in the late 1970’s 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 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 papers published until 2010 was reviewed previously by Cooper et al. Since that time, data on secular trends has become available for the first time for Ecuador, Iceland, Taiwan and Lebanon, new nationwide studies from Sweden, Norway, Turkey, Australia and updated data are available from Finland, Denmark, Greece, Korea, China (Beijing) and Hong-Kong which are all included in our analyses. In addition, we have included data on secular trends in different ethnic groups in the United States. Leslie et al, recently performed a brief update on the information presented by Copper et al, and included some, but not all, of the countries we covered above, and did not cover the new studies in Asia.

Our approach differs substantially from the 2 prior papers in several aspects. Most importantly we performed an extensive study exclusively focusing on hip fractures from 1966 till 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 we showed an increase in rates from 1989 until 2000 followed by a stabilization until 2005, and a decrease in rates from 2005 till 2008. In Germany, this new data 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, while many regions of Asia are experiencing sustained increases in fracture rates, rates in two highly developed areas, Hong Kong and Taiwan, are seeing declining rates 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 1970’s in the UK, until the late 1980’s and mid-late 1990’s in the USA, 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, 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, while 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 US and in 1970 at 75.7% in Canada, the trend break in hip fractures occurred in the mid-1990’s in the US and by mid-1980’s, 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, or other lifestyle factors.
It 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\textsuperscript{80}.

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 USA, a Medicare study by Brauer et al\textsuperscript{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 USA. In Canada,\textsuperscript{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\textsuperscript{25} analyzing trends in anti-osteoporotic medication prescriptions in parallel to hip fracture incidence showed a six fold 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% - 1.3% of prevented fractures in men and only 1.9% - 3.7% of prevented hip fractures in women could have been attributed to specific therapy.\textsuperscript{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 et al\textsuperscript{81} demonstrated an increase in bone mineral density in non-Hispanic US white women, between the two periods 1988-1994 and 2005-2008. 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)\textsuperscript{82} also documented increasing body size and weight over this time period with the prevalence of overweight and obesity in US adults rising from 56% in 1988-1994 to 64% in 1999-2000. Higher body weight has consistently been associated with greater bone mineral density (BMD) and lower rates of bone loss.\textsuperscript{83} A recent meta-analysis of 12 prospective population-based cohorts\textsuperscript{84} has also demonstrated a lower risk for hip fractures with higher BMIs (risk ratio per unit higher BMI of 0.93 (95% CI,0.91-0.94, p < 0.001). These associations suggest that increasing BMI may be a contributor to the secular decrease in hip fracture rates
observed in the USA and other Western countries. Leslie et al, 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.\textsuperscript{85} Whether the temporal increases in bone density observed in the US 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,\textsuperscript{86} Sweden,\textsuperscript{34} Canada,\textsuperscript{87} Korea\textsuperscript{88} and Portugal\textsuperscript{89} 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, while 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 US and Hong Kong women\textsuperscript{68, 90} 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,\textsuperscript{91} improvement in physical activity\textsuperscript{92} and calcium intake and vitamin D status,\textsuperscript{25, 93} and fall prevention,\textsuperscript{68, 94, 95} 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 due 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, UK, USA and Canada.\textsuperscript{96} 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.\textsuperscript{97}
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 that 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 because of demographic changes alone.\textsuperscript{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.\textsuperscript{29, 31, 58, 59} In Beijing, China for example, the data from public records was found to underestimate the rates of hip fractures in 1990-1992 by 75% largely because of miscoding of intertrochanteric fractures.\textsuperscript{9} 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.\textsuperscript{8, 28, 50-52, 58, 59, 67} Other studies had a short time span for secular trend analysis,\textsuperscript{8, 23, 60, 63, 64, 71, 72} 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 due to aging of the world’s population alone, with the majority of this increase expected in the developing countries. However, if a 1% secular increases 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.\textsuperscript{7} Furthermore, the projected number of hip fractures in 2050 will be 5 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 FRAX calculator. The FRAX formula uses the country-specific (and, in the USA, 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 US, 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. In developing countries with rapidly rising rates of fractures, and improved longevity, FRAX calculations will significantly underestimate fracture probability if not updated frequently.

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 as 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.

Disclosure: “All authors state that they have no conflicts of interest.”
References:


Centers for Disease Control and Prevention.


Authors’ roles:

Study design: GB, ML, JC, GEHF
Study conduct: GB
Data collection: GB and GEHF
Data analysis: GB and GEHF
Data interpretation: GB, ML, JC, GEHF
Drafting manuscript: GB
Revising manuscript content: GB, ML, JC, GEHF
Approving final version of manuscript: GB, ML, JC, GEHF
Takes responsibility for the integrity of the data analysis: GEHF
Figure legend:

Secular trend in hip fractures by continent in men (Figure 1) and women (Figure 2).

For country-study selected, the percent annual change in age-standardized hip fracture rates for men and women is calculated between 2 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 2 time points. The result is expressed in % change/year.
Table 1. Percent annual change in age-standardized hip fracture rates in women and men worldwide

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<th>Region</th>
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R: regional study  N: national study

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

\(^{1}\) For country-study selected, the percent annual change in age-standardized hip fracture rates for men and women is calculated between 2 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 2 time points. The result is expressed in % change/year.

\(^{2}\) All studies using age-standardized rates to an external population
Figure 2