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ORIGINAL ARTICLE

Latitude, socioeconomic prosperity, mobile phones and hip fracture risk

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Abstract
Introduction Epidemiological observations suggest that sunlight exposure is an important determinant of hip fracture risk. The aim of this ecological study was to examine the relationship between latitude and hip fracture probability.
Methods Hip fracture incidence and mortality were obtained from literature searches and 10-year hip fracture probability computed from fracture and death hazards.
Results There was a significant association between latitude and 10-year hip fracture probability. For each 10° change in latitude from the equator (e.g., from Paris to Stockholm), fracture probability increased by 0.3% in men, by 0.8% in women and by 0.6% in men and women combined. There was also a significant association between economic prosperity and hip fracture risk as judged by gross domestic product (GDP)/capita or the use of mobile phones/capita. A US $10,000 higher GDP/capita was associated with a 1.3% increase in hip fracture probability. The association between latitude and hip fracture probability persisted after adjusting for indices of economic prosperity.
Conclusions These findings provide support for an important role of sunlight exposure in the global variation of hip fracture risk. In addition, there is a need to identify the factors related to socioeconomic prosperity that may provide mechanisms for the variation in hip fracture probability worldwide.

Keywords Hip fracture · Latitude · Mobile phones · Socioeconomic prosperity

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Introduction

Osteoporosis is a major healthcare problem because of the fractures that arise. Of the fractures due to osteoporosis, hip fracture is associated with the highest long-term reductions in quality of life, mortality and cost for society [1]. The global burden of hip fracture has been estimated at approximately 1.3 million fractures annually [2–4].

The available evidence suggests a large heterogeneity in fracture risk between countries and, for example, hip fracture rates vary by more than tenfold between countries [5, 6]. The high burden of fracture, together with the heterogeneity in risk, suggests that geographic variations in risk indicators may provide clues that would be helpful in the development of preventive strategies. Although reasons for this heterogeneity of risk are conjectural, there is evidence, however, that low sunlight exposure may be an important risk factor for hip fracture [7] and within Sweden hip fracture rates vary by latitude [8].

Hip fracture risk also appears to be related to socioeconomic prosperity [9, 10].

The objective of the present study was to explore the relationship between hip fracture risk, socioeconomic prosperity and latitude. A secondary objective was to determine whether such information might be able to be used to estimate hip fracture rates in those regions of the world where such information is unavailable.

Methods

Hip fracture rates in men and women aged 50 years or more were obtained in 5-year age bands from published sources by literature searches where possible in the last 12 years. For some countries, regional estimates were used from a single survey. The majority were hospital register studies and details are provided in an earlier paper [11]. This source was updated by more recent reports from Belgium, Morocco, the Cameroon, Brazil, Mexico and Iran [12–16]. The increase in risk with age was computed from the logarithm of incidence by age.

Mortality estimates were obtained from the World Health Organization (WHO) for each country as the number of deaths for the year 1999 in 5-year age bands in men and women together with the population size. Expected survival was computed from the age of 50 years using a Poisson model described previously [11].

Ten-year hip fracture probabilities were computed from the hazard functions of hip fracture and death. Ten-year probabilities were computed at the age of 50, 60, 70 and 80 years in men and women. Where more than one estimate was available for a country, the average probability was taken. For each country and sex, an average probability at 50, 60, 70 and 80 years was taken as a summary variable [11]. For both sexes combined, the average value for men and women was taken.

Hip fracture rates included individuals with more than one hip fracture discharge so that the incidence of a first hip fracture is overestimated. In Sweden the overestimate increases with age from 0% at the age of 50 years to 14 and 20% in men and women, respectively, aged 85–89 years [17]. The overestimate is offset, at least to some extent, by the decreasing death rate in most countries.

The latitude for each country was assumed to be that of the capital city since these have the highest population density. The indices of socioeconomic prosperity were the gross domestic product (GDP) per capita and the use of mobile phones/10,000 of the general population obtained from the *World Factbook* at the Central Intelligence Agency [18]. A linear regression model (GLM) and a partial correlation model were employed (SAS) using an ordinary least squares estimation.

Results

In the 35 countries, the average 10-year probability of hip fracture varied from 0.1 to 5.7% in Norway. The GDP per capita ranged from US $1,700 to US $37,600 and the latitude from 1° from the equator to 64° (Table 1).

Latitude and hip fracture probability

There was a significant correlation ($p<0.0001$) between latitude and hip fracture probability ($p<0.001$) in the regression model for both men ($r=0.65$), women ($r=0.65$) and men and women combined ($r=0.67$; Fig. 1). For each 10° latitude difference from the equator there was a +0.3% increment in 10-year probability in men, a +0.8% increment in 10-year probability in women, and for men and women combined a +0.6% rise in 10-year probability (Table 2). For example, at a latitude of 40°, the hip fracture probability was estimated at 2.6% in men and women combined, but rose to 3.2 at a latitude of 50°. A possible outlier was Singapore with a relatively high fracture probability (0.3%) at the equator. There were two few points south of the equator to identify any difference in the relationship between latitudes north or south.

Socioeconomic prosperity and hip fracture probability

There was a significant linear correlation between GDP per capita and the 10-year hip fracture probability in men ($r=0.73$), in women ($r=0.84$) and in men and women combined ($r=0.83$; $p<0.001$) (Fig. 1). For each increase of US $10,000 of GDP/capita the hip fracture probability was increased by +1.3% for men and women combined (Table 2). South Korea appeared to be an outlier with a lower than expected hip fracture risk for its GDP.

There was also a significant linear correlation between the use of mobile phones and hip fracture probability in men ($r=0.64$), women ($r=0.69$) and men and women combined ($r=0.65$), but the correlation coefficients were lower than those with GDP/capita and were no longer significant when adjusted for GDP/capita.

A significant relationship persisted between latitude and hip fracture probability when adjusted for GDP/capita. For each 10° increase in latitude hip fracture probability increased by 0.3 in men and women ($r=0.50$). The association also persisted after adjustment for the use of mobile phones (Table 2). Conversely, socioeconomic prosperity (GDP/capita) remained a significant association with hip fracture probability after adjustment for latitude ($r=0.58$) (Table 2). There was, however, a significant interaction between GDP and latitude in that high latitude had a more pronounced effect to increase fracture risk in those countries with the greater wealth. When both latitude

Table 1 Ten-year hip fracture probability (%) in different regions of the world according to gross domestic product (GDP) and latitude

Country	GDP/capita (US $000)	Latitude (°)	Mobile phones (/10,000)	10-year hip fracture probability		
				Men	Women	Men & women
United States	37.6	39	53.6	2.5	5.4	3.9
Norway	31.8	60	89.1	3.7	7.7	5.7
Switzerland	31.7	47	82.4	2.0	5.6	3.8
Belgium	30.6	51	78.6	–	4.2	–
Canada	29.4	46	41.3	2.4	5.1	3.7
Denmark	29.0	56	88.9	2.7	6.1	4.4
Japan	28.0	36	70.6	1.3	3.5	2.4
Australia	27.0	34	71.5	2.2	5.2	3.7
Netherlands	26.9	52	76.2	2.1	4.8	3.5
Germany	26.6	53	79.0	1.9	5.2	3.6
Finland	26.2	60	90.4	2.5	4.4	3.4
Hong Kong	26.0	22	104.3	1.6	3.1	2.3
France	25.7	49	68.2	1.4	3.2	2.3
Sweden	25.4	59	87.8	3.8	6.9	5.3
United Kingdom	25.3	52	82.8	2.0	4.9	3.4
Iceland	25.0	64	96.4	2.9	6.5	4.7
Italy	25.0	42	96.4	1.3	5.3	3.3
Singapore	24.0	1	79.5	1.3	2.7	2.0
Spain	20.7	40	93.8	1.6	3.5	2.6
South Korea	19.4	37	70.0	0.3	0.3	0.3
Greece	19.0	38	84.0	2.5	3.5	3.0
Portugal	18.0	39	88.6	1.5	3.4	2.4
Taiwan	18.0	25	109.6	2.2	4.1	3.1
Kuwait	15.0	29	60.1	1.3	1.6	1.4
Hungary	13.3	47	68.0	2.1	3.0	2.5
Argentina	10.2	40	16.3	0.7	1.9	1.3
Chile	10.0	33	40.0	0.2	0.4	0.3
Mexico	9.0	20	26.5	1.5	2.8	2.2
Iran	7.0	34	4.9	0.8	1.0	0.9
Brazil	7.6	12	24.9	0.6	1.7	1.1
Turkey	7.0	40	39.9	0.7	0.2	0.5
Venezuela	5.5	10	25.6	0.5	0.9	0.7
Morocco	4.4	32	22.3	0.5	0.6	0.5
China	4.4	40	20.6	0.9	0.9	0.9
Cameroon	1.7	4	6.1	0.1	0.1	0.1

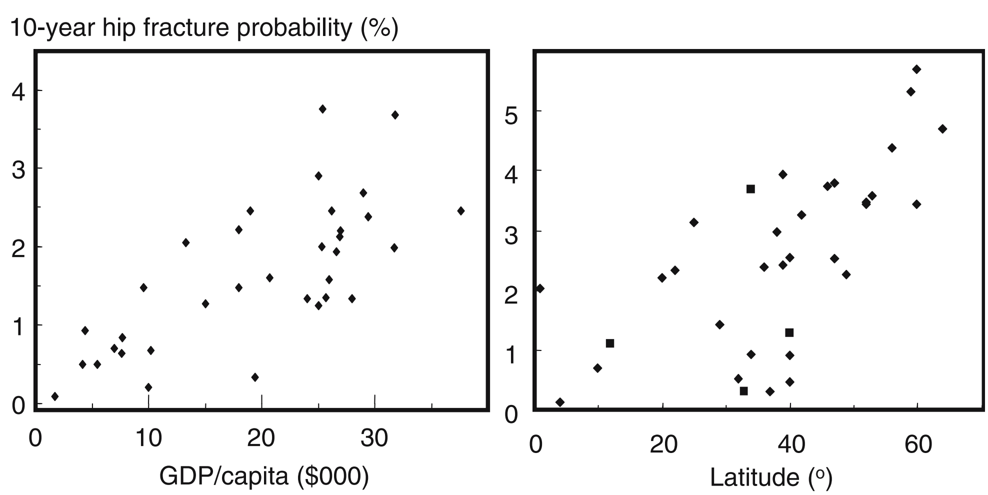

Fig. 1 Correlation between average 10-year hip fracture probability in different countries and latitude, and GDP per capita. *Square symbols* in the right hand figure refer to countries south of the equator

Table 2 Increment in 10-year probability of hip fracture (%) according to latitude, GDP/capita and the use of mobile phones

Variable	Increment	Men	Women	Men & women
Latitude	10°	0.4***	0.8***	0.6***
GDP/capita	US $10,000	0.7***	1.8***	1.3***
Mobile phones	per 10,000	0.2***	0.5***	0.3***
Latitude[a]	10°	0.2**	0.4*	0.3**
Latitude[b]	10°	0.3**	0.6**	0.5**
GDP/capita[c]	US $10,000	0.5**	1.5***	1.0***

[a] Adjusted for GDP/capita
[b] Adjusted for mobile phones
[c] Adjusted for latitude
*$p<0.05$; **$p<0.01$; ***$p<0.001$

and GDP/capita were considered the correlation coefficients were 0.79 in men, 0.87 in women and 0.87 in men and women combined, and the coefficients of determination 62, 75 and 76%, respectively.

Discussion

The principal finding in this paper is the significant correlation between hip fracture probability and both latitude and socioeconomic prosperity. These two factors appeared to be independent, and with a model including both factors, 76% of the variance was explained.

The association between latitude and hip fracture risk may plausibly be related to vitamin D status, since the bioavailability of vitamin D is dependent not only on dietary sources but also on exposure of the skin to sunlight, which decreases at higher latitudes. Recent studies have emphasised the poor vitamin D status in the general population, and in particular in the elderly [19–23]. As noted in the introduction, lack of sunlight exposure was found to be a significant risk factor for hip fracture in a large case-control study of several European countries. Hip fracture risk increased in a dose-dependent manner, and patients in the lowest quartile of sunlight exposure in the recent past had a twofold increase in hip fracture risk when cases were categorised to be above or below the median exposure to sunlight. The attributable risk was 8% [7]. Observational and intervention studies suggest that vitamin D supplementation may decrease hip fracture risk [22, 24–27], though the evidence is inconsistent [28]. These various observations emphasise the importance of vitamin D for musculoskeletal health, but add no additional weight to the hypothesis that poor vitamin D status is causally related to the international variation in hip fracture probability. It is merely a hypothesis that hides behind a cloak of plausibility. Factors that are of importance within communities may not be important indicators of risk within communities. For example, deficiencies in calcium nutrition may contribute to fracture risk within communities, but differences between communities are not explained by differences in calcium intake [6].

A similar situation holds for the association of hip fracture risk with socioeconomic prosperity in that the association does not prove causality. If so, the confiscation of mobile phones would be a plausible intervention strategy. Rather, it is likely to be a surrogate. A plausible candidate is the level of physical activity which, within countries, declines with advancing socioeconomic prosperity. Another possibility is the increasing hardness of the environment so that fracture becomes more likely after a fall. Notwithstanding, they remain hypotheses. In contrast, it is well recognised that poor socioeconomic status within countries is related to poor health [29] and higher healthcare costs [30–32], but a recent study reported higher hip fracture rates in the poorer communities of California [10].

Irrespective of the causality or otherwise of the associations, the correlations might be helpful in estimating the global burden of disease. The number of hip fractures worldwide is estimated to be approximately 1.3 million annually [3, 4, 33]. These studies are, however, based on incidence figures from only 35 countries, the majority of which are in the developed world. The correlation, although less than perfect for prediction, may be adequate for sensitivity analyses of the global burden of disease.

We conclude that both latitude and socioeconomic status are markers of hip fracture risk in a global (ecological) perspective. If the association between sunlight exposure and hip fracture is causal, global strategies to improve vitamin D status could have a marked impact on the burden of disease.

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