The rising number of underfoot accidents after the menopause causes both fractures and non-fracture injuries

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Summary

To test our hypothesis that the onset of the menopause would be associated with an increased number of underfoot accidents in the female population for both fracture and non-fracture injuries, we analysed 90,061 accidents recorded by the Home Accident Surveillance System and classified them as to (a) whether a fracture resulted, and (b) whether they were ‘underfoot’. We defined ‘underfoot’ accidents to have an event such as a trip, slip, missed footing, twisted or turned ankle, on the level or on stairs. All other accidents, including falls from or off structures, or falls caused by medical conditions were classified as ‘not underfoot’. Overall, 51.3% of women and 32% of men were injured in underfoot accidents. There was an increase with age in the percentage of fractures in both men and women, mainly due to an increased risk of fracture in underfoot accidents: underfoot accidents caused 75.9% of all fractures in women and 55.4% in men. The number of women who had fractures following underfoot accidents increased sharply after the age of 50 years, and the number continued to rise up to 80 years. The number of non-fracture injuries in elderly women from underfoot accidents also increased with age. Osteoporosis on its own does not explain our result, and changes in muscle strength and reaction time, with age in both men and women, and at a greater rate in postmenopausal women, may be an important factor in underfoot accidents.

Introduction

It was reported in 1962 that the incidence of distal forearm fractures in women rises dramatically between the ages of 40 to 60 years, then remains approximately constant; by contrast, men show little change. Later studies obtained similar results and revealed that most types of fracture have an increased incidence in elderly women with low bone density. Over half of women and about a third of men will experience osteoporotic fractures during their lives. It is widely believed that the higher incidence of fracture in postmenopausal women is caused by osteoporosis, although some studies have emphasized multifactorial causes. The difference in incidence of osteoporotic fractures between communities is greater than that between sexes within communities, which suggests that the importance of gonadal insufficiency in women has been over-emphasized and that other factors, probably lifestyle influences affecting peak bone density, account for aetiological differences in incidence between communities and secular trends within communities. A study of Gambian women revealed a lower bone density than in UK White women of comparable age, although minimal trauma fractures were uncommon. A population survey of forearm fractures in Oxford showed that the stepwise increase in the incidence of distal forearm fractures around the age of 50 is due to an increased risk of falling interacting with osteoporosis. Later studies confirmed...
that postmenopausal women are more likely to fall than younger women.\textsuperscript{6} The UK Health and Safety Executive discovered that the incidence of major occupational injuries due to falls rises sharply after the age of 45 in women but not in men.\textsuperscript{10} Studies among women at work in Sweden and the UK found an increased relative risk of a ‘fall on the level’ and a ‘fall from height’ above 45-years-of-age, even though older women were not exposed to hazards different to younger women.\textsuperscript{10} However, this study could not distinguish an increased risk of falling \textit{per se}, as distinct from sustaining a fracture.

None of these studies recorded the causes of the falls, but accident data collected by the Merseyside Accident Information Model (MAIM) includes information on the mechanism of the accident; the first unexpected event (first event) such as a trip or slip can be distinguished from a fall that is a later event in the accident sequence. Underfoot first events including foot slipped, tripped, missed edge of step, twisted a foot or ankle etc can be grouped together. We define ‘underfoot’ accidents to have an event such as a trip, slip, missed footing, twisted or turned ankle, on the level or on stairs. All other accidents, including falls from or off structures, or falls caused by medical conditions are classified as ‘not underfoot’.

In studies using MAIM of patients attending a hospital accident and emergency department and fracture clinics, we found that women experience a higher incidence of underfoot accidents with increase in age.\textsuperscript{11} In another study using MAIM, we found that 48% of patients attending hospital fracture clinics had been injured by an underfoot accident (61% women and 39% men) and that disability following discharge from hospital affected 40% of women and 18% of men; fully 79% of female patients reporting disability had been injured by an underfoot accident or loss of balance.\textsuperscript{12} Analysis of two studies of patient interviews using MAIM have shown that women are more likely to have underfoot accidents requiring hospital treatment, increasingly with advancing age for both fracture and non-fracture injuries.\textsuperscript{13}

These studies\textsuperscript{11–13} were based on relatively small numbers of patients (~5000 in total), and it could be argued that the accidents may not have been sufficiently representative of the national population. We present the findings from an analysis of a large database compiled by the Home Accident Surveillance System (HASS). The aim of the study was to discover using nationwide large-scale statistics whether the increased risk of women suffering a fracture after the menopause was associated with a higher incidence of non-fracture injuries and of underfoot accidents. Our hypothesis was that the onset of the menopause would be associated with an increased number of falls in the female population for both fracture and non-fracture injuries.

**Methods**

**The Home Accident Surveillance System data**

The data analysed were collected as part of HASS by the Consumer Safety Unit of the UK Department of Trade and Industry (DTI).\textsuperscript{14} HASS has been in place since 1976, collecting accident details from patients attending selected hospitals for treatment following accidental injuries in the home. The hospitals were selected to give a representative (national) view of accidental injuries requiring hospital treatment. Clerks at each of the participating hospitals conducted face-to-face interviews with adult patients. Interviewers supplemented information from the personal interview from medical records. Where it was not possible to conduct a personal interview, data were recorded from medical records alone. The DTI provided us with data on ~150 000 accidents from their 1998 HASS study. Each accident record included the age and gender of the patient, a description of the injury, a free text description of the circumstances of the accident and also the HASS accident mechanism assigned by the interviewer. The free text description of each accident was generally sufficiently detailed to allow a meaningful assessment of the cause of the accident.

**Event structure of accidents**

The conceptual model of accidents that we use describes them as sequences of events, starting with the first unexpected incident perceived by the patient, usually followed by a short sequence of distinct events that lead to injury. This approach allows us to differentiate between causes of accidents and causes of injuries.\textsuperscript{15} For example an accident where someone tripped, fell into a fire and suffered burns would probably be classified as a \textit{burn or thermal effect} in the HASS system. However if the immediate cause of the accident, the trip, could have been avoided, there would have been no injury. For this reason, we would classify this accident as underfoot (a trip).

**Underfoot accidents**

We defined underfoot accidents to have the following characteristics: (i) tripped, slipped, missed footing, lost balance, twisted ankle or twisted foot was the first unexpected event in a sequence of events that lead to injury; (ii) this need not have resulted in
a fall; (iii) we included accidents on stairs and fixed steps; (iv) we excluded falls from ladders, step-ladders, and falls off structures (such as walls and furniture); (v) we excluded falls where the immediate cause was a medical condition (such as fitting). Medical records were available to the interviewers and medical conditions relevant to the accident were noted in the free text description.

Accidents were classified by inspecting the free text description provided in the HASS data. The classification was done by one author (JCD). The amount of data necessitated that the process of classification be automated as far as possible; however, many of the words and phrases used (such as slip and fall) did not unequivocally define the accident as underfoot, and visual inspection of the data was required. The field in the database used to indicate UNDERFOOT was initially set to null (no data). The process of classification was performed in stages. First, we identified manageable portions of data with appropriate combinations of key words; for example, the field underfoot was marked after visual inspection of each accident description, and where no judgement could be made, the data were coded as missing. The process then continued using different key words on the remaining accidents (with UNDERFOOT set to null). Accidents simply recorded as 'fall' or 'fell' with no other detail, were classified as underfoot accidents, assuming that falls from height would be described in more detail such as ‘fell 4 feet’.

Fractures

Injuries for each patient were described in free text in the HASS data. Patients suffering fractures were identified by searching for the word ‘fracture’. This had the effect of including the possible fractures where the patient had been interviewed before medical diagnosis.

Data analysis and presentation

Data are presented as a function of age-band, either absolute numbers of patients, or percentages: standard errors of percentages are calculated as \( \sqrt{\frac{p(1-p)}{N}} \) where \( p \) is the proportion of fractures and \( N \) is the number in each band.

Results

All accidents

Children under the age of 15 years were excluded from our study. Of the remaining 92 811 cases, in 284 neither age nor gender were recorded, leaving 92 527 valid cases (40 429 men and 52 098 women). We were unable to classify 2.7% (2466) of these on the basis of our definition of underfoot accidents, either because the interviewer had been unable to ascertain the circumstances, or because the description of the accident was inadequate. This left 90 061 accidents for analysis.

Underfoot accidents analysed by gender and age

Of the 90 061 classifiable accidents, we classified 43.0% (38 737) as underfoot. When analysed by gender, 32.4% (12 760/39 419) of the men and 51.3% (25 997/50 642) of the women had underfoot accidents in all, increasing above the age of 50 to 42.7% (5742/13 433) of the men and 64.1% (15 702/24 490) of the women. Figure 1 shows the raw distribution of underfoot and non-underfoot accidents by age and gender, and Figure 2 shows the percentage of underfoot accidents by age and gender.

HASS accident mechanisms compared to our classification of underfoot accidents

Accident recording systems that classify accidents into single categories have problems when a particular accident could be legitimately placed in several of the available groups. We compared our simple classification of underfoot accidents with those given in the HASS data. Table 1 compares the main HASS accident mechanisms with our classification of underfoot accidents.

Fracture injuries

Underfoot accidents caused 75.9% (6699/8827) of all fractures in women and 55.4% (2368/4271) in men. Figure 3a shows the distribution of underfoot and non-underfoot accidents by gender and age within the group attending with fractures. In women who had fractures following underfoot accidents there is a discontinuous increase in numbers between the five-year age bands of 45–49 and 50–54 years. Figure 3b shows a sub-set of the data from Figure 3a, with the age-scale expanded to one-year bands; this pinpoints the sharp increase in numbers for women suffering fractures from underfoot accidents to between the ages of 49 and 51 years. Figure 4 shows the percentage of women (Figure 4a) and men (Figure 4b) sustaining fractures for underfoot and non-underfoot accidents in five-year age bands.
Non-fracture injuries

The distribution of underfoot and non-underfoot accidents by gender and age within the group attending with non-fracture injuries is shown in Figure 5.

Discussion

Scope and accuracy of the data

The purpose of the HASS system is to provide a national representative view of accidents in the
home in the UK, and forms the basis of annual summaries of accident classifications and objects involved. Comparison of the accident mechanisms used in the HASS system in successive years gives a consistent view of the accuracy and reliability of the data. For example the national estimate for ‘falls on/from ladders’ in the two years 1997 and 1998 were 27 673 and 27 363, respectively. In 1998, a mean of 48.2% of all patients with home accidents who attended A&E at the participating hospitals were recorded in the HASS system. The majority of these (71.1%) were based on ‘face-to-face’ interviews when patients attended during ‘office hours’, supplemented by assessment of medical records where no interview was possible. Adult patients attending because of accidents in the home represent about one third of all accidents treated in A&E units in the UK.

The classification system used by the HASS system allows a single accident mechanism to be recorded. The free text record of the accident recorded by the interviewer preserved the structure of the accident history and allowed us to identify underfoot accidents. The problems of simple classification systems are illustrated in Table 1 where underfoot events clearly form only a part of more complex accident structures.

**Importance of underfoot accidents**

We have used a very simple classification (underfoot true/false) to discover the number of underfoot accidents within the HASS home accident data. As many as 64% of women aged over 50 years attended hospital for accidental injuries caused by loss of either balance or footing. In postmenopausal women, the number attending because of underfoot accidents was larger than the number attending for all other accidents combined.

The number of non-fracture injuries in elderly women from underfoot accidents increases with...
Figure 4. Percentage fracture in the ‘underfoot’ and ‘non-underfoot’ accident groups in a women and b men. Error bars show standard error.

Figure 5. Distribution of ‘underfoot’ and ‘non-underfoot’ accidents by gender and age within the group attending for non-fractures.
increasing age (Figure 5). This shows that the rise in the numbers of postmenopausal women attending hospital following underfoot accidents is not solely due to osteoporosis.

The number of underfoot accidents in the UK is unknown, because there are no national data on the number of injuries treated by NHS hospitals and no information on the causes of attendance at accident and emergency departments. We classified 43% of the accidents in the 1998 HASS study as underfoot; using the national estimate of 1.8 million attendances to A&E reported in the HASS study, this suggests that there are 0.78 million underfoot home accidents per annum in the UK. A similar calculation on the data from the Leisure Accident Surveillance System (LASS) gives a national estimate of 0.81 million underfoot ‘leisure’ accidents per annum. Thus in one year, approximately 1.6 million of the adult population in the UK (3.6% based on the 1991 census) attended A&E because of underfoot accidents in domestic or leisure activities. We can further estimate that, of these, 0.65 million were women aged 50 and over attending because of underfoot accidents. By comparing underfoot accidents in men and women above and below the age of 50, we estimate that in one year there are approximately 0.3 million excess attendances at A&E in the UK as a result of underfoot accidents in postmenopausal women (excluding occupational injuries).

These accidents cause considerable disability. The British Orthopaedic Association estimates the total number of new fracture patients in England as nearly 900,000 per year. A random survey of 800 fracture patients seen by 30 surgeons found that 50% of patients had disability one year after injury, and 30% of patients had morbidity that was inevitable regardless of facilities.

Despite the uncertainties in the number of underfoot accidents treated by the NHS and the number of disabilities following from them, it is evident that underfoot accidents are a major burden on the community, the NHS and the Social Security budget. Determining their causes and devising preventative strategies are priority areas for research.

**Mechanisms: bone versus neuromuscular mechanisms**

Walking is controlled falling. Although it is possible to recover from ‘near miss’ underfoot incidents, a defective ability to balance (because of poor reaction time or reduced muscle strength) makes a fall more likely.

Osteoporosis increases the risk of fracture once an underfoot incident has occurred. However the onset of osteoporosis is gradual, and the discontinuous increase seen in Figure 3 probably cannot be explained by the risk of fracture alone. A possible explanation is an increase in the risk of underfoot accidents in the group of women likely to fracture, so that this group would incur a double risk. Why might this be?

Overall reaction time is a function of time taken for afferent signal transmission, central processing, efferent signal processing, and physical execution of the appropriate movements. Decreased reaction and movement time is associated with lower circulating oestriadiol. Older women are less able than younger women or older men to recover balance by taking a single step during a forward fall, apparently because of a reduced maximum speed of foot movement. Hammars reported an improvement in postural balance in postmenopausal women following oestrogen treatment. Schultz found that muscle strength and speed of muscle contraction were more important in the maintenance of balance and recovery than neural factors, and speculated that this explained the greater frequency of falls in older than younger adults and in older women than older men. The age-related performance on some cognitive functions, including reaction time, is notably accelerated following the menopause. Muscle strength declines in post-menopausal women, and this is reversible by hormonal replacement therapy.

If we assume that the occurrence of ‘not underfoot’ accidents has no age bias, then the age-dependence of the fractures that result (Figure 4a and b) reveals the ‘baseline’ effect of osteoporosis in women and men. It can be seen that this percentage increases with age in postmenopausal women, but not in men. We suggest that this reflects the gradual reduction in bone mineral density in women. By contrast, in underfoot accidents both men and women show an increase in the percentage of fractures with age, with in addition a marked increase in women over 50 years. If our argument is correct, this sharp postmenopausal increase is not (solely) explained by the gradual effect of osteoporosis on the susceptibility to fracture. Rather, we suggest, the increase in numbers of underfoot accidents in women over 50 years seen in Figure 1 is at least substantially explained by the decline in muscle strength and reaction time. Of course the ‘bone’ and ‘neuromuscular’ hypotheses are not mutually exclusive, and indeed their interaction might explain much of the detail shown in Figure 4.

**Mechanisms: an integrated view**

At least four components in underfoot accidents may contribute to patients attending A&E.
(i) The incident that causes loss of balance. After the menopause women have reduced muscle strength.\textsuperscript{25} We found that women holding items were more likely to have underfoot accidents.\textsuperscript{11}

(ii) Inability to recover balance. Both men and women have increased reaction time with age,\textsuperscript{26} and especially women after the menopause.\textsuperscript{24}

(iii) Inability to reduce severity of impact following the fall. The forces that do damage operate over short periods. Reflex actions that increase the duration of impact will be beneficial and help reduce the risk of fracture. The percentage of fractures in both men and women has a rising trend with age (Figure 4). There is no obvious reason why women should be more at risk than men, but we speculate that poor reaction time could have an effect on avoiding injury.

(iv) Increased risk of fracture due to osteoporosis. The lower graph (not underfoot) in Figure 4\textsuperscript{a} shows that, for women, there is a small increase in the risk of fracture in non-underfoot accidents with age after the menopause, which fits the gradual age-dependence of osteoporosis. For men, the equivalent curve (not underfoot) in Figure 4\textsuperscript{b} is flat from 15 to 80 years. This model explains many of the characteristics of the curves in Figure 4. The double risk element, with reaction time implicated both in the cause of the accident and the increased risk of fracture, would explain the discontinuous increase in the number of fractures seen in Figure 3\textsuperscript{a}. In this hypothesis, there is an increased risk of fracture in ageing women even if osteoporosis is absent. An alternative hypothesis would posit a group of women with low bone mineral density, who after the menopause would have an increased risk of falling (because of declining muscle strength or increased reaction time) combined with increased risk of fracture (due to low bone mineral density). Recognized risk factors for fractures include menopausal state, low bone mineral density, body weight, body mass index, impaired vision, previous fall, infrequent walking, use of diuretics, psychotropic drugs, self-reported arthritis, smoking and car ownership.\textsuperscript{3,6,7,27} Many of these will correlate with poor health or poor fitness and the consequent adverse effects on strength and reaction time. Kelsey,\textsuperscript{27} in a study of fractures of the distal forearm and proximal humerus, reported that although reaction time was not originally measured in the study, a retrospective examination of reaction time in the cohort suggested that reaction time could be a potential predictor of fractures.

In summary, the rise in percentage of fractures in both men and women with increase in age is mainly due to an increased risk of fracture in underfoot accidents. The effect of osteoporosis, on its own, does not explain the data reported here. Change in muscle strength and reaction time, with age in both men and women, and at a greater rate in postmenopausal women, may be the main reason for the increased risk of fracture with age. These internal biological risk factors interact with environmental hazards to cause underfoot accidents and research into the influence of floor surfaces, contaminants and footwear should proceed in association with human factors research in support of a successful initiative to reduce this national epidemic of injuries.

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**References**


