# Urban vs rural increase in hip fracture incidence

## Age and sex of 901 cases 1980–89 in Olmsted County, U.S.A.

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To determine if hip fracture incidence rates are greater in urban than in rural areas of the United States, as they appear to be in Scandinavia, we undertook a study in Olmsted County, Minnesota. During the decade 1980–89, the age- and sex-adjusted incidence of proximal femur fractures among urban residents of the central city of Rochester was 36 percent greater than among residents of the rural remainder of Olmsted County. The difference was almost entirely accounted for by an excess of fractures due to moderate trauma in elderly urban women. These first detailed results from the United States confirm earlier observations from Scandinavia that hip fracture rates are lower in rural areas.

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Submitted 92-08-29. Accepted 93-05-02

Scandinavian studies have demonstrated a greater incidence of proximal femur (hip) fractures in urban compared to rural populations (Reikerås et al. 1984, Falch et al. 1985, Finsen and Benum 1987, Mannius et al. 1987, Sernbo et al. 1988, Jarnlo et al. 1989, Larsson et al. 1989). The excess urban rates persist after age-adjustment, and the gap may be widening over time (Mannius et al. 1987, Larsson et al. 1989). It is uncertain whether or not these observations are generalizable to other regions. In Canada, the incidence of hip fractures in Saskatchewan cities was 27 percent greater than in rural areas in the province (Ray et al. 1990) but, in Scotland, hip fracture incidence rates were 22 percent higher for women from the vicinity of Dundee, Scotland, than for women residing in Dundee itself (Swanson and Murdoch 1983). Likewise, an analysis of United States Medicare data indicated that age-adjusted hip fracture incidence rates for elderly white women were higher in counties that had a greater percentage of the total land area in farms (Jacobsen et al. 1990). The latter was an ecological analysis, however, and did not consider the place of residence of individual patients.

Before pursuing pathophysiologic hypotheses that might account for an urban excess in hip fracture risk, it is important to establish that this is a universal finding, but no detailed examination of this issue has been carried out in the United States. In order to assess whether rates are higher in urban areas of the United States when individual men and women with hip fractures are considered, we determined the incidence of hip fractures among residents of Olmsted County, Minnesota, during the period 1980–89, and contrasted rates for the city of Rochester with those for the remainder of the county, which is largely rural.

## Patients and methods

Population-based epidemiologic research can be conducted in Olmsted County because medical records for the entire population are available from almost all providers of care. Most orthopedic and trauma care is provided by the Mayo Clinic, which has maintained a common medical record system with its 2 large affiliated hospitals (St. Mary's and Rochester Methodist) for 85 years. This dossier-type record contains both inpatient and outpatient data, and the diagnoses and surgical procedures recorded in these records are entered into a computerized index. Medical records of the other providers who serve the local population, most notably the Olmsted Medical Group and its affiliated Olmsted Community Hospital, are indexed into the same system (the Rochester Epidemiology Project) and are also retrievable for study. Using this data base, we identified every Olmsted County resident with a diagnosis (ICD 820) or surgical procedure that might have indicated a hip fracture during the 10-year period 1980 through 1989, whether these were recorded for outpatients seen in office or clinic consultations, emergency room visits or nursing home care, or for hospital inpatients, at autopsy examination or on death certificates. Because of the complete community coverage and the redundancies built into this data system, we believe that all hip fractures which were clinically diagnosed during this period were identified.

The complete (inpatient and outpatient) medical record of each candidate case was retrieved and reviewed for the occurrence of a cervical or trochanteric fracture of the proximal femur. Since the original radiographs were not available, the assessment of fracture site was based on the radiologist's report and the surgical narrative of the orthopedist. Subtrochanteric fractures and those more distal on the femur were excluded, as were the uncommon isolated fractures of the greater or lesser trochanter. Radiographic or autopsy confirmation was obtained for each fracture. From data in the medical records, the immediate cause of fracture was classified by convention as severe trauma (motor vehicle and recreational accidents and falls from heights), moderate trauma (the equivalent of a fall from standing height or less) or pathology (specific local lesions, mostly metastatic malignancies).

In calculating incidence rates, the entire population of Olmsted County was considered to be at risk. Denominator age- and sex-specific person-years (p-y) were estimated from decennial census data for Olmsted County, with linear interpolation between census years (Bergstralh et al. 1992). Olmsted County is a Metropolitan Statistical Area and contains 1 centrally located city, Rochester, and 13 small towns or villages. Rochester had 56,447 residents in 1980 and 69,995 in 1990. This corresponds to an estimated 625,452 p-y of observation during the decade, 1980–89. Rochester is considered synonymous with urban for the purposes of this study. The remainder of the county is mostly farming country with a 1980 population of 34,116 and a 1990 population of 35,725 and an estimated 348,395 p-y of observation. The rest of Olmsted County is considered rural in this study, even though 3 percent of the county population lived on the outskirts of Rochester in 1990 and a further 4 percent lived in 1 small town with a population of 4,500. Ages were grouped as 0–34 years, 35–44 years, 45–54 years, 55–64 years, 65–74 years, 75–84 years, and 85 or more years.

It is assumed that, given a fixed number of person-years, the number of incidence cases follows a Poisson distribution. This allows for the estimation of standard errors and/or the calculation of confidence intervals for incidence rates. The rates are age- and/or age-sex-adjusted to the 1990 U.S. white population distribution by expressing adjusted rates as weighted averages of crude rates. The standard errors and/or confidence intervals of adjusted rates are based on the same assumptions. Inferences regarding crude incidence rate ratios (e.g., urban rates vs rural rates) are based on the same Poisson assumptions and the suggested approximation by the Cox method (1953). The standard errors of adjusted rates are estimated using a Taylor Series approximation for the ratio of independent random variables. This approximation used the means and standard errors of the adjusted rates.

The relationships of crude incidence rates to age, sex and residence (urban/rural) were assessed using generalized linear models assuming a Poisson error structure (McCullagh and Nelder 1983). Such models fit the natural logarithms of the crude incidence rates as linear combinations of gender, age-group and residence, using the statistical package GLIM (Baker and Nelder 1985). In our model, we first fit gender and age-group, testing for an interaction between them. Residence is then added to the models. Model fit is assessed using the model deviance, which is a measure of how well the observed and predicted incidence rates agree. The model fits the data reasonably well if the expected value of the deviance is approximately equal to its degrees of freedom. Such models were developed separately for all fracture rates, moderate trauma fracture rates, severe trauma fracture and pathological fracture rates. For all causes of fractures, the cervical and trochanteric rates were also analyzed separately.

Survival after hip fracture was estimated by life-table methods (Kaplan and Meier 1958). These estimated (observed) mortality rates were compared, using the 1-sample log-rank test, to expected rates based on the 1980 white population in the West North Central region of the United States and taking into account the age-sex distribution of the hip fracture patients. Survival curves of urban and rural dwellers were compared using the 2-sample log-rank test statistic (Kalbfleisch and Prentice 1980). The statistical procedures used were taken from the Supplemental Library of SAS (SAS 1986).

## Results

There were over 4 times as many hip fractures among Rochester residents (n 733) as for residents of the rest of Olmsted County (n 168), but the Rochester population was almost twice as large. Taking the denominators into account, the crude hip fracture incidence rate was two and a half times greater among Rochester residents (117 versus 48 per 100,000 p-y). However, the Rochester population was also older on average, and age-adjustment of the rates accounted for most of the remaining difference. The age- and sex-adjusted incidence among Rochester residents (125 per 100,000 p-y; 95 percent CI, 116–134) was only 36 percent

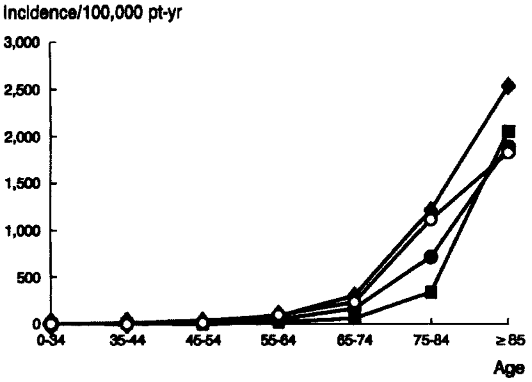


Figure 1. Age-specific incidence of first hip fractures among Olmsted County, MN, men and women by urban or rural residence.
◆ Urban women. ○ Rural women. ● Urban men. ■ Rural men.

greater than the adjusted rate for rural residents (92 per 100,000 p-y; 95 percent CI, 78–106) although this difference was still significant (*P* 0.002). Since rural dwellers made up just 34 percent of the total population of Olmsted County, the effect of the modest urban excess on overall hip fracture incidence rates in the community was relatively small. The age- and sex-adjusted incidence of hip fractures in Rochester alone was only 8 percent higher than the overall rate for all of Olmsted County (116 per 100,000 p-y; 95 percent CI, 109–124).

Most hip fractures were the first that each patient had experienced. The incidence of these initial hip fractures was 30 percent greater among urban Rochester residents than among the residents of rural Olmsted County (110 per 100,000 p-y; 95 percent CI, 102–119 versus 85 per 100,000 p-y; 95 percent CI, 72–98; *P* 0.008). Only 11 percent of the 901 hip fractures observed were repeat fractures, and they comprised 12 percent of all fractures in Rochester compared to 8 percent in the rest of Olmsted County. Since the discrepancy in rates was mostly accounted for by differences in the risk of a first hip fracture, the remainder of the analysis was confined to the 798 initial fractures.

The incidence of first hip fractures doubled between ages 75–84 and 85 years and over among Rochester women, while the rate of increase was less among rural women (Figure 1). We did not collect medication or comorbidity data in this study, but 5-year relative survival rates following an initial hip fracture were somewhat less (*P* 0.10) for Rochester residents (47 percent observed, 64 percent expected; 74 percent relative survival) than for those living in the rest of Olmsted County (56 percent observed, 68 percent expected; 82 percent relative survival), indicating that Rochester residents may have been less healthy, even after taking their older ages into account. This might suggest a migration of less healthy elderly rural residents into Rochester, although the incidence rate for rural men aged 85 years and over does not seem consistent with this hypothesis, since it is slightly higher than the incidence among urban men in that age-group (Figure 1). However, the latter observation is based on only 15 rural cases during 10 years in a population of 73 men aged 85 years and over.

Altogether, age-adjusted first fracture rates were 46 percent greater in Rochester men (*P* 0.08) and 23 percent higher in Rochester women (*P* 0.07) compared to their rural counterparts. Incidence rates generally were higher in women than men, however, so in absolute terms women contributed as much as men to the overall urban excess, which was seen in 10 of the 14 age- and sex-specific comparisons (Table 1). The difference in rates between Rochester and the remainder of Olmsted County was almost entirely due to the fractures resulting from moderate trauma (Table 2). Adjusted rates were not different between the 2 populations for fractures due to severe trauma or those due to specific pathological lesions. There seemed to be little influence of fracture type on the urban:rural ratio, which was similar for both cervical (1.3:1) and intertrochanteric fractures (1.2:1), as shown also in Table 2.

Using Poisson regression, we investigated the effects of gender, age-group and residence on the natural logarithm of the incidence rate of hip fractures. There were highly significant differences among age-groups and between the genders, with marginal evidence of an age-gender interaction primarily reflecting the tendency for the rates among the females to begin increasing at an earlier age. Adjusting for these effects, there was a significant urban-rural difference (*P* 0.001) with consistently higher urban rates. The resulting model was found to fit well, with the model deviance of 18.9 not being significantly different from the 13 degrees of freedom (Table 3). Following the same adjustments, urban rates were higher for cervical (*P* 0.01) and for intertrochanteric fractures (*P* 0.04), separately, and for moderate trauma fractures (*P* 0.001), which comprised 85 percent all cases. Severe trauma fractures made up 14 percent of the total. Here there were highly significant differences betweem age-groups and between genders, but no age group-gender interaction. After adjusting for these factors, there was no significant difference between urban and rural residents. Finally, pathological fractures made up only 1 percent of the fractures. An age-group difference was still detected, but there was no difference between genders or urban/rural residents.

Table 1. Comparison of first hip fracture incidence rates by age and sex among Olmsted County, MN, residents, 1980–89

| | Rochester | | Rest of Olmsted County | | | |
|---|---|---|---|---|---|---|
| | n | Rate[a] | n | Rate[a] | Ratio | 95% CI |
| *Men* | | | | | | |
| <35 | 4 | 2 | 3 | 3 | 0.7:1 | 0.2–3.6 |
| 35–44 | 3 | 7 | 3 | 11 | 0.6:1 | 0.1–3.3 |
| 45–54 | 3 | 11 | 0 | 0 | – | 0.6– |
| 55–64 | 11 | 52 | 3 | 23 | 2.3:1 | 0.7–9.0 |
| 65–74 | 23 | 168 | 5 | 64 | 2.6:1 | 1.1–7.4 |
| 75–84 | 51 | 719 | 12 | 341 | 2.1:1 | 1.2–4.1 |
| ≥ 85 | 41 | 1893 | 15 | 2058 | 0.9:1 | 0.5–1.7 |
| Subtotal | 136 | 47 [b] | 41 | 23 [b] | 2.0:1 | 1.4–2.9 |
| (Adjusted) | | 80 [c] | | 55 [c] | 1.5:1 | 0.9–2.0 |
| *Women* | | | | | | |
| <35 | 6 | 3 | 2 | 2 | 1.5:1 | 0.4–8.9 |
| 35–44 | 6 | 14 | 0 | 0 | – | 1.2– |
| 45–54 | 12 | 41 | 3 | 16 | 2.6:1 | 0.8–9.8 |
| 55–64 | 21 | 86 | 12 | 100 | 0.9:1 | 0.4–1.8 |
| 65–74 | 65 | 306 | 19 | 236 | 1.3:1 | 0.8–2.2 |
| 75–84 | 202 | 1219 | 48 | 1119 | 1.1:1 | 0.8–1.5 |
| ≥ 85 | 195 | 2542 | 30 | 1830 | 1.4:1 | 0.96–2.1 |
| Subtotal | 507 | 151 [b] | 114 | 66 [b] | 2.3:1 | 1.9–2.8 |
| (Adjusted) | | 130 [c] | | 106 [c] | 1.2:1 | 0.98-1.5 |

[a] Age- and sex-specific incidence per 100,000 p-y.
[b] Crude sex-specific incidence per 100,000 p-y.
[c] Age-adjusted sex-specific incidence per 100,000 p-y.

Table 2. Comparison of first hip fracture incidence rates by trauma and site of fracture among Olmsted County, MN, residents, 1980–89

| | Rochester | | Rest of Olmsted County | | | |
|---|---|---|---|---|---|---|
| | n | Rate[a] | n | Rate[a] | Ratio | 95% CI |
| *Trauma* | | | | | | |
| Severe | | | | | | |
| Men | 27 | 14 | 12 | 12 | 1.2:1 | 0.3–2.1 |
| Women | 55 | 15 | 17 | 15 | 1.0:1 | 0.5–1.6 |
| Both sexes | 82 | 15 | 29 | 13 | 1.2:1 | 0.6–1.6 |
| Moderate | | | | | | |
| Men | 107 | 65 | 28 | 41 | 1.6:1 | 0.9–2.3 |
| Women | 449 | 114 | 97 | 91 | 1.3:1 | 0.97–1.5 |
| Both sexes | 556 | 95 | 125 | 71 | 1.3:1 | 1.1–1.6 |
| Pathological | | | | | | |
| Men | 2 | 1 | 1 | 2 | 0.5:1 | 0.0–2.0 |
| Women | 3 | 1 | 0 | 0 | – | – |
| Both sexes | 5 | 1 | 1 | 1 | 1.0:1 | 0.0–5.9 |
| *Fracture site* | | | | | | |
| Cervical | | | | | | |
| Men | 76 | 45 | 19 | 22 | 2.0:1 | 0.96–3.2 |
| Women | 256 | 68 | 63 | 57 | 1.2:1 | 0.9–1.5 |
| Both sexes | 332 | 58 | 82 | 43 | 1.3:1 | 1.01–1.7 |
| Intertrochanteric | | | | | | |
| Men | 60 | 34 | 22 | 33 | 1.0:1 | 0.5–1.6 |
| Women | 251 | 62 | 51 | 48 | 1.3:1 | 0.9–1.7 |
| Both sexes | 311 | 50 | 73 | 41 | 1.2:1 | 0.9–1.5 |

[a] Incidence per 100,000 p-y age-adjusted for men and women or age- and sex-adjusted for both sexes combined.

Table 3. Overall Poisson regression model of hip fracture incidence among Olmsted County, MN, residents, 1980–89

| Effect | Change in deviance | DF | *P*-value |
|---|---|---|---|
| Age-group | 3252 | 6 | < 0.001 |
| Female gender | 226 | 1 | < 0.001 |
| Age-group, female | 13 | 6 | 0.05 |
| Urban residence | 10 | 1 | 0.001 |
| Model | 19 | 13 | 0.1 |

## Discussion

Our study confirms the Scandinavian finding of greater hip fracture incidence among urban residents of the community. This result was not due to ascertainment bias since we canvassed all providers who could have cared for hip fracture patients and we believe case ascertainment to be complete for rural as well as urban residents of the County. Nor do we believe that differential access to care can explain our findings with regard to hip fracture. Though most of Olmsted County is rural, with a population density of only 57.3 people per square mile, which is equivalent to the most rural quintile of communities in New York State (Mahoney et al. 1990), no place is isolated; no one in the county is more than 23 miles from the most sophisticated medical care available at Mayo Clinic. Moreover, care would not be withheld for an emergency condition like hip fracture regardless of a patient's ability to pay.

The older average age of Rochester residents did account for much of their excess hip fracture risk, but the urban:rural differential was 1.36:1, even after age differences in the 2 populations had been accounted for. This is consistent with the magnitude of the urban hip fracture excess found in Scandinavian studies (Finsen and Benum 1987, Sernbo et al. 1988, Jarnlo et al. 1989, Larsson et al. 1989), despite the fact that we may have underestimated the differential by including residents on the urban fringe of Rochester within the rural population. Indeed, data from both Norway and Canada reveal a gradient of rising hip fracture incidence with increasing urbanization (Finsen and Benum 1987, Ray et al. 1990). Such results may in part be artifactual if urban populations are older on average within each age-group, as age-adjustment is incomplete in such circumstances. Among Olmsted County residents aged 85 years and over, for example, the mean age was 89.1 years among urban and 88.5 years among rural residents, but the median age was 88 years in each instance.

One explanation for a real urban excess in hip fracture risk may be that city people have more coexisting medical problems, leading to a greater burden of secondary osteoporosis or to an increased risk of falling. We previously documented a net migration of women with diabetes mellitus (Melton et al. 1983) and breast cancer (Melton et al. 1980) into Rochester from surrounding areas, thus increasing the prevalence of such conditions among urban residents. Indeed, increasing urbanization is associated with greater morbidity and mortality generally, suggesting a bias towards health in rural areas, with the ill and disabled moving to town. Some evidence for this hypothesis is provided by the observation that utilization rates for many interventions, e.g., total hip arthroplasty (Melton et al. 1982), are higher among Rochester residents than in those who reside in rural Olmsted County. Likewise, 7 of the 8 Olmsted County nursing homes are located in Rochester, and the hip fracture risk is greater in nursing home residents.

Alternatively, the higher fracture incidence among urban populations has been attributed to less physical activity, with a consequent reduction in bone mass (Finsen and Benum 1987, Mannius et al. 1987, Larsson et al. 1989, Lau et al. 1990). The association between physical activity and bone mass is well documented, and lower bone mineral content has been found in city men and women compared to their rural peers (Gärdsell et al. 1991). No study has yet examined the correlation between activity patterns and bone mass in urban and rural populations, but the close correlation (*R* 0.94) between hip fracture rates and the number of motor vehicles in use (Lewinnek et al. 1980) is suggestive of an increased reliance on laborsaving devices by city dwellers. The observation by Gärdsell et al. (1991) that people who lived in rural areas for the first 25 years of their lives before moving to the city had higher bone mass than lifelong urban dwellers also suggests the value of exercise at a young age in establishing optimal peak bone mass. Indeed, Hui et al. (1990) estimate that a woman's bone mass at age 70 years is determined equally by her peak bone mass and her subsequent bone loss. The risk of fractures appears to be greater in lifelong urban as compared to lifelong rural residents (Jónsson et al. 1992), but we were unable to assess residence history in the present study.

We were also unable to assess other factors that might be differentially distributed by urban and rural residence. For example, alcohol use and cigarette smoking have been associated with hip fractures and their higher consumption among urban dwellers has been suggested as an explanation for the increased incidence (Falch et al. 1985, Finsen and Benum 1987, Mannius et al. 1987). This is an unlikely explanation for our findings, however, since most hip fractures in both the urban and rural areas occurred among elderly women who smoke and drink relatively little. Certainly, alcohol and cigarette usage patterns are out of line with secular hip fracture trends in the community, insofar as the age-adjusted incidence among women has remained stable for 3 decades in the face of rising cigarette and alcohol use (Melton et al. 1987). Likewise, variations in dietary habits would not be expected in Olmsted County, which is ethnically and culturally homogeneous. Poverty has been implicated in the etiology of hip fractures (Jacobsen et al. 1990), but it is not clear to what extent this reflects the influence of differences in physical activity or comorbidity which, as noted previously, are important determinants of bone mass and fracture risk.

## Acknowledgements

The authors wish to thank Mrs. Judy Bruen and Mrs. Janet Deaner for data collection, Ms. Nancy Houar for help with data analysis, and Mrs. Mary Roberts for assistance in preparing the manuscript. This investigation was supported in part by research grants AG-04875 and AR-30582 from the National Institutes of Health, United States Public Health Service. Dr. Madhok's stay at the Mayo Clinic was made possible by the RI Stirling Bequest, Edinburgh, Scotland.

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