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An indirect method for the estimation of osteoporotic fractures from injury and fracture profiles

Summary

Study objective was to develop a valid epidemiological method for the estimation of osteoporotic fracture risk, using administrative databases and accounting for variable baseline risks of injury. Design is the secondary analysis of inpatient and outpatient utilization data. A baseline injury risk was estimated by the incidence of primary utilization of medical services for soft tissue injuries (ICD-9 diagnostic codes 910–929), and the risk profile was compared after normalization with the overall primary utilization rate for fractures (ICD-9 diagnostic codes 800–829). The setting is a county with approximately 100,000 inhabitants in the former East Germany. Participants were all inhabitants of the county who had a physician contact (inpatient or outpatient) during 1987–1988, as well as hospital inpatients for all of Germany in 1989. The number of fractures increased with age, especially in women, when compared to the number of fractures expected from the incidence of soft tissue injury. Similar patterns were identified in hospitalization data from East and West Germany. Estimating the prevalence of osteoporosis directly from certain "osteoporotic" fracture types associated with higher age is potentially biased, since it neglects the underlying risk of injury. Our model distinguished the osteoporotic fracture risk as the excess risk over an expected injury-related fracture risk for a given age and sex, and may allow a more valid quantification of osteoporotic fractures in different populations.

The prevalence of osteoporosis, and with it the incidence of osteoporotic fractures, increases with age. The prevention or delay of osteoporotic changes at a population level, for example by food supplementation with calcium and vitamin D or by estrogen replacement therapy[1,2] is one possible remedy. Attention may also be directed toward preventing falls, influencing life styles[3–6], or cushioning the effect of falls by protective garments (e.g. "hip protectors")[7,8]. Both approaches are important, and may also be effective in younger age groups, but it may be difficult to estimate the potential benefit of a given intervention for a given age, sex, and population.

Utilization data or administrative data bases can be used to estimate the osteoporotic fracture risk in a population[9]. Traditionally, certain types of fractures in higher age groups are classified as "osteoporotic", e.g. fractures of the proximal femur, pelvis, distal radius and vertebrae, or fractures of these locations following "minimal trauma" in the presence of osteoporosis. The lifetime risk has been estimated by these direct methods as 30–40% for women and 15% for men[10,11]. However, this approach is imprecise, as it neglects the underlying risk of injury, which extends into old age and may even increase with age.

A fracture is basically caused by an imbalance between the mechanical strength of a bone and the stress applied to it. Although the mechanical strength of human bone decreases with osteoporotic changes at higher ages, fractures are neither an inevitable consequence nor caused exclusively by these changes. Elderly people may have an increased injury risk due to a number of factors, including more frequent falls due to poor vision or poor gait, reduced shock absorption etiology of many fractures in old age may be characterized better by an increased vulnerability to injuries rather than simply by

osteoporotic bone. Conversely, the influence of osteoporotic changes may be underestimated at younger ages. We were therefore interested in developing a model which might help to separate the contributing factors of host and environment, and might suggest whether the resources of a given society should be directed more towards nutritional and hormonal interventions or towards injury control.
Our model for a probabilistic estimation of the osteoporotic fracture risk is based on several assumptions, which are made explicit in the section on methods and discussed later. These assumptions also define potential limitations.

Methods

A retrospective approach was used to model the age- and sex-specific fracture risk and a corresponding baseline injury risk for the study populations. Data were obtained from a population-based study on the utilization of inpatient or outpatient medical services in the county of Zittau in East Germany with approximately 100,000 inhabitants during 1987–1988. Each incident of primary utilization of medical services in the course of a disease during the 12-month observation period was recorded and classified by an ICD-9 code at the three-digit level. The incidence of fractures for each sex and age group was estimated from the overall primary utilization rate for ICD-9 diagnostic codes 800-829 and constituted the "fracture profile" for this population.
Sensitivity, i.e. the classification of fracture cases as such, and specificity, i.e. the exclusion of non-fracture cases from these diagnostic codes, were not evaluated. Misclassification of fracture types within these groups, however, would have no adverse effect on this aggregated analysis, and misclassification between aggregated diagnostic groups generally is less common than between subgroups. Fractures that did not require medical attention were not included and would lead to an underestimation of total cases; erroneous double registrations would produce an overestimation of cases. No data are available for a quantitative evaluation of these potential sources of error.
Our model introduces the concept of an "injury baseline" or "injury profile" for a population, which we can define as the number of fractures expected in the population for a given age and sex if there were no age-related changes in bone strength. The "injury profile" of the population under study was estimated using the incidence of soft tissue injuries (ICD-9 diagnostic codes 910–929, including superficial injuries, contusions, and crushing injuries). This approach adjusts both for an age- and sex-specific injury risk and for the fact that the same type of injury could require different care depending on the age of the patient. The soft tissue injury risk was regarded as representative of the baseline risk of injury of all kinds for a given age and sex, and is independent of the strength of the bones. We hypothesized that the effect of osteoporosis could thus be separated from the baseline pattern or "profile" of injuries requiring medical attention in a given population. Absolute numbers are not important for this approach, because the diagnostic codes 910–929 were only used to assess relative variations between sexes and between age groups. Complete registration of soft tissue injuries is not necessary as long as the types of soft tissue injuries brought to medical attention for a given age and sex remain fairly constant for a given population, and missed incidents will not cause bias if they occur nondifferentially.
The injury profile was calculated by multiplying the incidence of soft tissue injuries in a given group by the ratio of fractures to soft tissue injuries observed for the appropriate sex at age 20–24 years, since it could be assumed that no relevant structural deterioration of bone would be present in a population at that age. The injury profile thus allowed the estimation of an "excess" fracture rate as the difference between observed and expected numbers for a given age and sex. The authors are aware of the distinction between the epidemiologic definitions of the dimensionless "risk" and the person time-related "rate", but use these expressions interchangeably for reasons of general understandability.
In order to demonstrate the general applicability of this method, we also analyzed published hospitalization data from 1989 (the last year before German unification) for the entire German Democratic Republic (East Germany)[12] and for the insured population of the Federal Republic of Germany (West Germany)[13]. For the West, fewer age groups were available for this comparison, and we also had to assume that the age distribution of the insured population of the Federal Republic of Germany was similar to that of its entire population. This assumption seemed reasonable, since 87% of the population that year did have insurance.

Results

The observations from the Zittau patients were in accordance with theoretical expectations: The observed fracture rates were higher than expected from the injury profile both in childhood and for the highest age groups. The gap widened increasingly with advanced age, and was more pronounced for females. The observed excess risk in children is consistent with the known vulnerability of growing bones, while the increasing excess of fractures with older age as well as the more pronounced excess among women have a biologic explanation in senile and postmenopausal osteoporotic changes. The results are presented for men and women respectively in Figures 1 and 2; in each graph, the area between the two curves represents the excess risk.

Hospitalization data for East and West Germany followed a similar pattern (Figures 3 and 4), although an excess of fractures in childhood could not be demonstrated. This can be explained by the fact that fractures in children generally do not require hospitalization, whereas they are frequently incapacitating in older persons. Data in the West were only available for insured citizens; however, this included 87% of the Western population in 1989. The observed fracture rates in the West were higher than in the East, most of which could be attributed to a generally increased injury rate.

Table 1 gives an overview of the Zittau population, the observed incidences of fractures, and the proportions attributable to osteoporosis under our model. We can estimate that about half the fractures in women and a quarter of those in men in East Germany were attributable to osteoporosis, while the remainder would be expected from their underlying vulnerability to injury. For West Germany, our more limited data suggest a similar effect of osteoporosis, but a higher risk of injury leading to a higher overall number of fractures in the elderly.

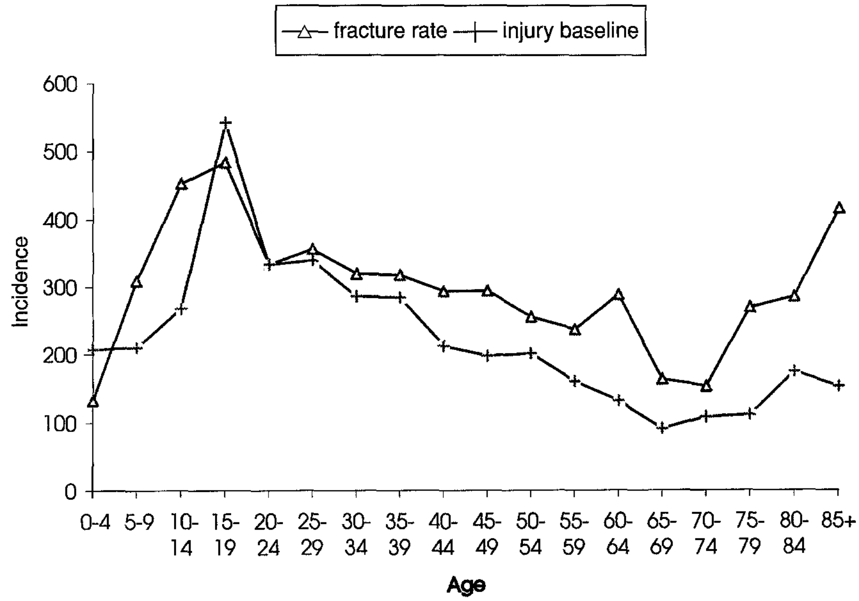

Figure 1. *Observed rate of fractures and injury baseline ("injury profile") calculated as described in the text per 10,000 of the male population of Zittau, 1987–1988. The area between the curves in adult age corresponds to the osteoporotic "excess risk".*

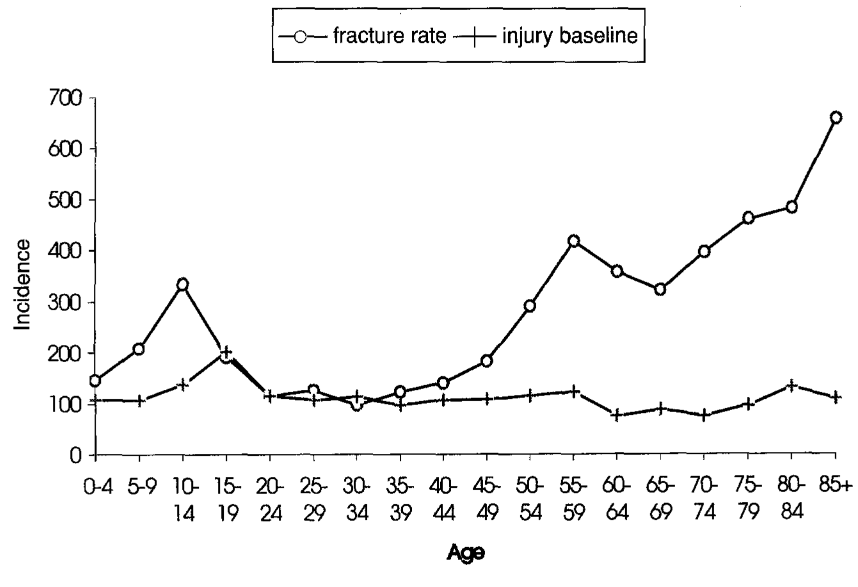

Figure 2. *Observed rate of fractures and injury baseline ("injury profile") calculated as described in the text per 10,000 of the female population of Zittau, 1987–1988. The area between the curves in adult age corresponds to the osteoporotic "excess risk".*

Discussion

The main idea of the method presented above is to estimate indirectly the osteoporotic fracture risk using soft tissue injuries as reference ("injury profile" of a population). The model presented here makes several assumptions, which must be carefully examined.

First, we assume that a general risk of injury exists, which can be thought of as due to individual and collective behavior, biologic sex and other genetic determinants, gender roles, occupation, social and marital status, macro- and microeconomic influences, health status and ageing. It is expected to vary during lifetime and between

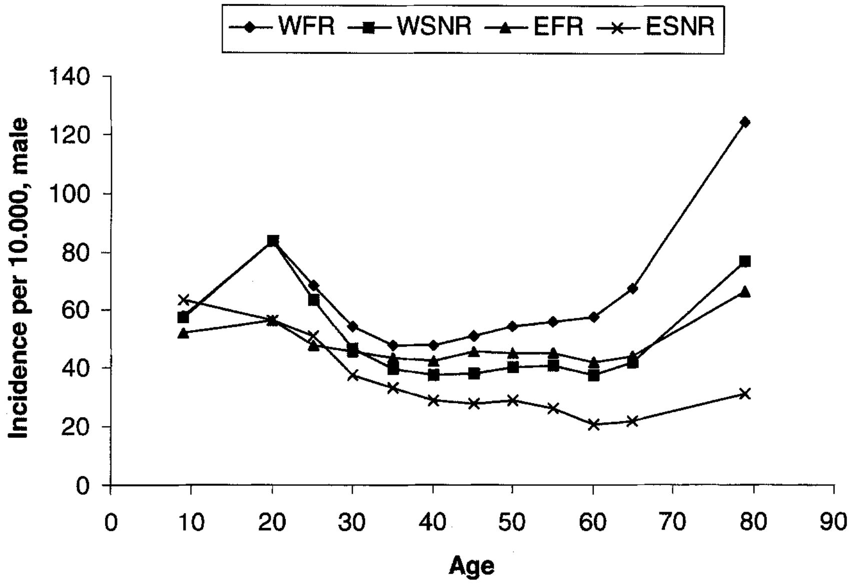

Figure 3. *Age-specific "injury profile" and "fracture profile", cumulative annual incidence of hospital discharges per 10,000 of the male study population. The area between the curves in adult age corresponds to the osteoporotic "excess risk" for East and West Germany in 1989, the last year before the German unification. East and West German rates follow similar patterns, although they differ in magnitude. The first value refers to age groups below 20, the last to age groups 70 and over. EFR: East German fracture rate; ESNR: East German soft tissue injury rate, normalized; WFR: West German fracture rate; WSNR: West German soft tissue injury rate, normalized.*

	Male	Female
Population	42,008	47,366
Fractures estimated from primary medical contacts	1,280	1,215
Fractures attributable to ageing	269	693
Excess fraction over a baseline injury risk, all ages	0.21 (CI 0.19–0.23)	0.57 (CI 0.54–0.60)
CI: 95 % Confidence Interval.		

Table 1. *Overall fractures and population numbers for the county of Zittau in East Germany. Excess fraction refers to the proportion of all fractures exceeding the expected numbers from an estimation derived from a reference (soft tissue injuries).*

sexes, as well as among cultures, economic conditions, and political systems. We also assume that this risk is homogeneous for individuals with and without osteoporosis in a population, and that its age- and sex-dependent dynamic is reflected by soft tissue injuries requiring medical attendance. Soft tissue injuries were selected as a reference, because age-related structural changes of these tissues are expected to contribute little to the injury risk, while other age-associated factors like poor vision, poor neuromuscular coordination, or risk-taking behavior play a role much as they do for fractures.

A further assumption of this model is that fractures at age 20–24 years are attributable completely for both sexes to non-osseous, injury-related extraneous factors. This generalization neglects metabolic diseases of bones at young age, but appears justified at a population level because those metabolic diseases are rare and therefore only exert a negligible influence on the overall fracture rate. Similarly, the excess risk at higher age is attributed exclusively to osteoporotic changes, disregarding other bone diseases. Again the argument in defense of this is the rarity of potentially competing diseases. Although this approach leads to a minor systematic overestimation of the etiologic share of osteoporotic fractures, it allows a more valid age- and sex-specific attribution of fractures to osteoporosis at a population level than conventional methods.

Our data estimate age- and sex-specific incidence rates of osteoporotic fractures indirectly from utilization data. Certain individuals will suffer repeated fractures, so that we cannot estimate a hypothetical lifetime risk. However, our observations fit with the basic epidemiology of fractures of the upper and lower limb among elderly Americans reported by Baron et al.[14], who showed a linear or ex-

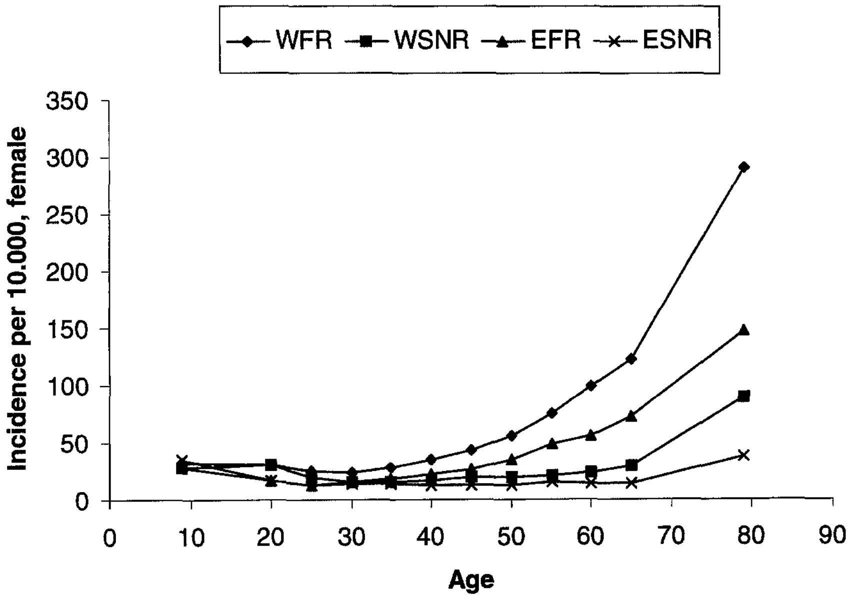

Figure 4. *Age-specific "injury profile" and "fracture profile", cumulative annual incidence of hospital discharges per 10,000 of the female study population. The area between the curves in adult age corresponds to the osteoporotic "excess risk" for East and West Germany in 1989, the last year before the German unification. East and West German rates follow similar patterns, although they differ in magnitude. The first value refers to age groups below 20, the last to age groups 70 and over. EFR: East German fracture rate; ESNR: East German soft tissue injury rate, normalized; WFR: West German fracture rate; WSNR: West German soft tissue injury rate, normalized.*

ponential increase for limb fractures apart from ankle fractures for both sexes in persons over 65 years. Hip fractures dominated with a relative proportion of 38% in their series, which explained the steep increase of the fracture risk in the highest age groups. Our data from East Germany show a similar trend[12]. However, the observed increase of the fracture risk with older age cannot be explained solely by a higher injury risk of the elderly, as is demonstrated by the widening gap between the injury baseline profile and the fracture profile. On the other hand, there is in fact an increased risk of injury in general in the older populations, so that osteoporosis likewise cannot be the only significant factor responsible for the increased incidence of fractures.

Accurate assessment of programs designed to minimize fractures in the elderly, including assessment of cost-effectiveness, will be increasingly important in the industrialized world, with a goal of maintaining functional independence in these diverse but growing populations[15,16]. Despite its limitations, our method for the indirect estimation of osteoporotic fracture risk is capable to adjust for a variable baseline risk of injury, and therefore has the potential to give more valid results than conventional methods. Our reference to the populations of Zittau and Germany 10 years ago is used only for reasons of convenience to illustrate this method. Profiling of the baseline injury risk should be repeated for other study populations, because the osteoporosis-attributable share of fractures may vary between populations and over time. The method presented may be used on its own or for cross validation of other methods of risk attribution from utilization data or administrative databases.

Zusammenfassung

Eine indirekte Methode zur Schätzung osteoporotischer Frakturen aus Unfall- und Frakturprofilen

Studienziel war die Entwicklung einer validen Methode zur Abschätzung des osteoporotischen Frakturrisikos unter Verwendung administrativer Daten und unter Berücksichtigung eines variablen Hintergrundrisikos für Unfälle. Studiendesign ist die sekundäre Analyse von Daten zur stationären und ambulanten Inanspruchnahme. Das Hintergrundrisiko für Unfälle wurde aus der Inzidenz der primären Inanspruchnahme der medizinischen Versorgung für Weichteilverletzungen (ICD-9 Kodierungen 910–929) geschätzt, und das Risikoprofil nach Normalisierung mit der allgemeinen primären Inanspruchnahme wegen Frakturen (ICD-9 Kodierungen 800–829) verglichen. Studienort war ein Landkreis mit etwa 100 000 Einwohnern in der ehemaligen DDR. Studienteilnehmer waren alle Einwohner des Kreises, welche 1987–1988 einen ambulanten oder stationären Arztkontakt hatten, sowie Krankenhausfälle in beiden deutschen Staaten im Jahr 1989. Die Anzahl der Knochenbrüche nahm mit dem Lebensalter zu, vor allem bei Frauen, verglichen mit der Anzahl, welche aus der Inzidenz der Weichteilverletzungen zu erwarten gewesen wäre. Ein ähnliches Muster war bei den Krankenhausfällen in Ost- und Westdeutschland zu beobachten. Die direkte Schätzung der Prävalenz der Osteoporose aus bestimmten "osteoporotischen" Frakturtypen, welche mit dem höheren Lebensalter verbunden sind, enthält potentiell einen systematischen Fehler, da ein Hintergrundrisiko für Unfälle vernachlässigt wird. Unser Modell identifiziert ein osteoporotisches Frakturrisiko als überschiessendes Risiko über ein nach Alter und Geschlecht zu erwartendes unfallbedingtes Frakturrisiko, und erlaubt potentiell eine validere Quantifizierung osteoporotischer Frakturen in verschiedenen Populationen.

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Résumé

Une méthode indirecte pour l'estimation du nombre des fractures ostéoporotiques de profiles d'accidents et de fractures

L'objective de la recherche était le développement d'une méthode valide pour l'estimation du risque d'une fracture ostéoporotique, utilisant données administratives et tenant compte des risques basales variables concernant les accidents. Le désigne de l'étude est l'analyse secondaire des données hospitalières et ambulatoires. Le risque basale des accidents fut estimé par l'incidence de l'utilisation première des services médicaux pour des blessures non-skeletals (ICD-9 codes 910–929) et cette risque fut comparé après normalisation avec la rate d'utilisation pour des fractures (ICD-9 codes 800–829). La recherche se concentrait sur un département de l'Allemagne de l'Est avec a peu près 100 000 habitants. Les participants étaient tous les habitants du département qui avaient un contact avec un médecin (a l'hôpital ou ambulatoire) pendant les années 1987–1988, ainsi que tous les cas hospitalisés dans toute l'Allemagne en 1989. Le nombre de fractures augmentait avec l'âge, en particulier parmi les femmes, comparé avec le nombre attendu de l'incidence des blessures. Des profils de risque pareils ont pu être observés parmi les cas hospitalisés de l'Allemagne de l'Ouest et de l'Est. L'estimation directe de la prévalence de l'ostéoporose a la base de certains types «ostéoporotiques» des fractures, associés avec le troisième âge, peut être incorrecte, parce qu'il néglige le risque basale pour les accidents. Notre modèle distingue le risque ostéoporotique de fracture comme un risque plus haut que le risque de l'accident attendu pour un certain âge et gendre, et permet une quantification plus valide des fractures ostéoporotiques parmi des populations différentes.

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