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Epidemiology of Childhood Fractures in Britain: A Study Using the General Practice Research Database

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ABSTRACT: A population-based British cohort study, including ~6% of the population, was used to derive age- and sex-specific incidence rates of fractures during childhood. Fractures were more common among boys than girls, with peak incidences at 14 and 11 years of age, respectively. At childhood peak, incidence rates were only surpassed later in life at 85 years of age among women and never among men.

Introduction: Fractures account for 25% of accidents and injuries in childhood; however, the descriptive epidemiology of childhood fractures remains uncertain.
Materials and Methods: Age- and sex-specific incidence rates for fractures at various skeletal sites were derived from the General Practice Research Database (a population-based British cohort containing computerized medical records of ~7,000,000 residents) between 1988 and 1998.
Results: A total of 52,624 boys and 31,505 girls sustained one or more fractures over the follow-up period, for a rate of 133.1/10,000 person-years. Fractures were more common in boys (161.6/10,000 person-years) than girls (102.9/10,000 person-years). The most common fracture in both sexes was that of the radius/ulna (30%). Fracture incidence was greater among boys than girls at all ages, with the peak incidence at 14 years of age among boys and 11 years of age among girls. Marked geographic variation was observed in standardized fracture incidence, with significantly ($p < 0.01$) higher rates observed in Northern Ireland, Wales, and Scotland compared with southeast England.
Conclusions: Fractures are a common problem in childhood, with around one-third of boys and girls sustaining at least one fracture before 17 years of age. Rates are higher among boys than girls, and male incidence rates peak later than those among females. At their childhood peak, the incidence of fractures (boys, 3%; girls, 1.5%) is only surpassed at 85 years of age among women and never among men. The most common site affected in both genders is the radius/ulna. Studies to clarify the pathogenesis of these fractures, emphasizing bone fragility, are now required.
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Key words: epidemiology, fracture, osteoporosis, childhood

INTRODUCTION

FEW DATA ARE available regarding the epidemiology of fractures in childhood. Most information comes from Scandinavian studies that have reported that the risk of sustaining a fracture from birth to 16 years of age is 42% among boys and 27% among girls. Fractures through the distal end of the radius seem most common, followed by fractures of the phalanges of the hand.[1] Other studies have focused on fractures at specific sites. Thus, the mean age of supracondylar elbow fractures in a Danish cohort was found to be 7.9 years, with an annual incidence rate of 308/100,000 person-years.[2] In contrast, an American study that used the Hospital Discharge Database of the Maryland Health Services Cost Review Commission for the years 1990–1996 reported annual rates of femoral shaft fracture of 19/100,000, with a bimodal peak of incidence at 2 and 17 years.[3] Such studies depend on referral to secondary care for identification of cases and cover relatively small population samples. To address these deficiencies and to provide comprehensive information on this important childhood public health problem in the United Kingdom, we used records from the General Practice Research Database to derive age- and sex-specific fracture incidence rates for children in this country during the period 1988–1998.

MATERIALS AND METHODS

General practitioners play a key role in the UK health care system, because they are responsible for primary health care and specialist referrals. The information in this study was obtained from the General Practice Research Database

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TABLE 1. DISTRIBUTION OF FRACTURES AND INCIDENCE RATES STANDARDIZED TO THE UK POPULATION

	Boys		*Girls*		*Both*	
Fracture site	*No. of cases*	*Rate per 10,000 py*	*No. of cases*	*Rate per 10,000 py*	*No. of cases*	*Rate per 10,000 py*
All	52,624	161.6	31,505	102.9	84,129	133.1
Radius/ulna	15,209	46.0	10,062	32.2	25,271	39.3
Carpal	12,152	36.7	4,702	15.0	16,854	26.1
Greenstick	6,627	17.3	4,805	15.5	10,462	16.4
Humerus	5,317	16.3	4,143	13.4	9,460	14.9
Clavicle	4,672	14.5	2,287	7.6	6,959	11.2
Foot	4,182	12.7	2,607	8.3	6,789	10.5
Tibia/Fibula	3,655	11.3	1,997	6.7	5,652	9.1
Skull	3,393	11.3	1,404	5.3	4,797	8.4
Ankle	1,690	5.1	1,043	3.3	2,733	4.2
Femur/hip	986	3.3	438	1.8	1,424	2.5
Patella	236	0.7	104	0.3	340	0.5
Ribs	233	0.8	106	0.4	339	0.6
Vertebral	159	0.5	134	0.4	293	0.5
Scapula	197	0.6	81	0.3	278	0.4
Pelvis	125	0.4	89	0.3	214	0.3

(GPRD), which contains the computerized medical records of 682 general practices in the United Kingdom. The population in GPRD is broadly representative of the UK population in age and gender structure, with a national coverage of about 6%.[4] There is a slight under-representation of smaller practices and of practices in inner London.[4] The data accrued include demographic information about the patients, prescription details, clinical events, preventive care provided, referrals to specialist care, hospital admissions, and their major outcomes. Clinical data are stored and retrieved by means of Oxford Medical Information Systems (OXMIS) and READ codes for diseases or causes of morbidity and mortality that are cross-referenced to the International Classification of Diseases, ninth edition (ICD-9). The data quality of each entry into GPRD is measured against specific targets, developed by comparisons with external statistics, to ensure research standards are met. Only data from practices that pass this quality control are compiled to form the GPRD. The general practitioners are expected to enter a minimum 95% of prescribing and relevant patient-encounter events.[4] Several independent validation studies have shown that the database has a high level of completeness and validity.[5,6] The GPRD is owned by the Department of Health and managed by the Medicines Control Agency in the United Kingdom. We evaluated the consistency of data recording over time, but found no substantive differences over time in the number of records with medical or prescription information.

The study population consisted of all permanently registered patients <18 years of age who had a fracture recorded in their medical record during the period of time from the enrollment date of their practice in GPRD until the end of data collection. The duration of data collection was from 1988 to 1998. The fracture types were classified according to the ICD-9 categories. These included skull (ICD-9 categories 800–804), vertebra (805 or 806), rib (807), pelvis (808), clavicle (810), scapula (811), humerus (812), radius/ulna (813), carpus (814 to 817), femur/hip (820/821), patella (822), tibia/fibula/ankle (823 or 824), foot (825 or 826), or unspecified fractures.(809, 818, 819, 827–829) A high level of validity for the recording of fractures in GPRD has been reported.[7]

Age- and gender-specific fracture incidence rates in the GPRD population were calculated by dividing the number of patients with a fracture by the total person-years of follow-up (detailed incidence estimates are available from the corresponding author). The total person-time was the sum of the number of patients registered on the database at July 1 of each calendar year. In the case of a patient suffering several fractures during follow-up, only the first fracture was used in the calculation of incidence rates. A directly standardized fracture rate was estimated. This was done by applying the age- and gender-specific incidence rates of each region to the age and gender structure of the population of England and Wales in 1992. The total number of cases per 10,000 children per year was estimated. Poisson regression was used to compare the incidence of fractures across regions of the United Kingdom. The relative rates (and their 95% CIs) were adjusted for age and sex.

RESULTS

A total of 52,624 boys and 31,505 girls sustained one or more fractures over the 11-year follow-up period, giving a rate of 133.1/10,000 person-years (py). Table 1 shows the distribution of fractures and the standardized incidence rates. Fractures were more common in boys (incidence rate, 161.6/10,000 py) than in girls (102.9/10,000 py). The most common fracture in both sexes was that of the radius/ulna, with a total of 39.3/10,000 py, but hand (26.1/10,000 py), greenstick (16.4/10,000 py), and humerus (14.9/10,000 py) fractures were also frequently recorded. The least common fracture in both sexes was pelvic fracture (0.3/10,000 py).

Figure 1 shows the age- and sex-specific incidence rates for all fractures within the cohort. Fracture incidence was

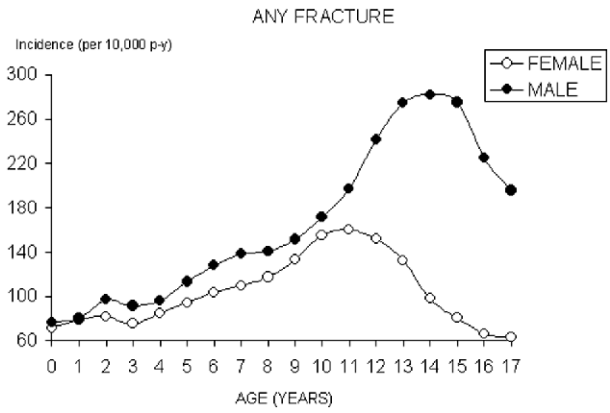

FIG. 1. Age- and sex-specific incidence of fractures at any site among children (to age 17 years) registered in the General Practice Research Database, 1988 to 1998. The figure provides rates per 10,000 person-years.

greater among boys than girls at all ages, with the peak incidence at the age of 14 years among boys and 11 years among girls; there was a sharp decline in rate thereafter.

Figure 2 shows the incidence patterns for different fracture sites by age and sex. Fracture rates increased smoothly from 4 to 17 years of age without any evidence of a plateau for rib fracture in both sexes. Rates stabilized or fell in late teenage years for the ankle, skull, patella, and tibia/fibula fractures in girls, but not in boys. The incidence of greenstick, humerus, radius/ulna, hand, foot, and clavicle fractures fell in the teenage period for both sexes. Very different patterns of tibia/fibula fracture incidence were seen in the two sexes; whereas a steady reduction in rate with age was observed in girls throughout childhood, the converse was true in boys. Hip fracture was extremely infrequent; its incidence was bimodal, with peaks observed in 0–2 year olds and a second peak in the late teenage years in boys. Scapular fracture was also uncommon in both sexes and varied little with age.

Table 2 and Fig. 3 show the distribution of fracture incidence standardized to the UK population by region. The southeast (total number of cases, 6696) was used as the reference region. Highest rates were observed in Northern Ireland (n = 2537; relative risk, 1.66; 95% CI, 1.58–1.74), Wales (n = 5147; relative risk, 1.60; 95% CI, 1.54–1.66), and Scotland (n = 3477; relative risk, 1.49; 95% CI, 1.43–1.56), with significantly elevated relative risk for fracture in all regions except Greater London (n = 6219; relative risk, 1.02; 95% CI, 0.98–1.05). There was also a marked seasonal variation in the incidence of fractures. The standardized incidence rate was 98.1 in the winter (December to February), 143.4 in the spring (March to May), 161.2 in the summer (June to August), and 129.6 in the autumn (September to November). There was no indication of a secular trend in the incidence of fractures, although the length of time period was limited. The standardized incidence rate of fracture was 138.0 in 1990 and 134.9 in 1997.

DISCUSSION

This study reports age- and sex-specific fracture incidence rates for children in England and Wales using a large, well-validated, national cohort study. We have shown that fractures were more common in boys than girls and that, while some fractures became more common in teenage years (vertebral, skull, rib, ankle, pelvis, patella), others were more common during earlier childhood (greenstick, humerus, radius/ulna, carpus, foot). Sexual dimorphism was most apparent for fractures of the tibia/fibula. Geographic variation in fracture incidence was apparent by region, which broadly replicated regional differences in standardized hip fracture incidence.

While only 6% of the total registered population of England and Wales is represented on the database, several independent validation studies have shown that the GPRD has a high general level of completeness and validity.[4] It is also broadly similar to the country as a whole in age and sex structure.

Accidents constitute a major cause of morbidity and mortality in childhood, and surveys of pediatric trauma have suggested that fractures contribute between 10% and 25% of all injuries.[8] However, few studies have attempted to describe age- and sex-specific fracture incidence rates in children or to characterize the incidence patterns at different skeletal sites. In the most comprehensive report,[1] based on the retrieval of all radiological reports of fracture in Malmo, Sweden, the overall annual incidence of fracture was 257/10,000 among boys and 165/10,000 among girls. These rates were based on around 8500 incident fractures and contrast with those in our study of 161.6/10,000 and 102.9/10,000 in boys and girls, respectively. The sites of fracture showed a remarkably similar pattern in the two studies, with fractures of the radius/ulna predominating, followed closely by fractures of the hand. The difference in overall incidence is in the same direction as the differences observed between Scandinavia and Britain in the incidence of hip and wrist fractures in later adult life. However, it may also have arisen through different methods of case ascertainment in the two studies: some of the less clinically severe fractures identified radiologically in the Malmo study may not have been reported back to primary care physicians and might not therefore have been recorded in the British study.

Landin[1] also described seasonal variation in the incidence of fractures in childhood, with high rates in May, lower rates in June/July, higher risk in autumn, and a second decline in December. Our results are in general accord with these findings, although we observed higher rates throughout the summer months. The difference might reflect a difference in the frequency and type of accidents between the two populations studied, as well as the differences in case ascertainment described above.

Other epidemiological studies have reported fracture rates in populations including children, and these include Scandinavian studies of scaphoid,[9] humerus,[10] ankle,[11] and tibial shaft[12] fractures, although breakdown of fracture rate into <10-year intervals is infrequent, making meaningful comparisons difficult. One of the few studies of the UK population[13] described the age and sex distribution of

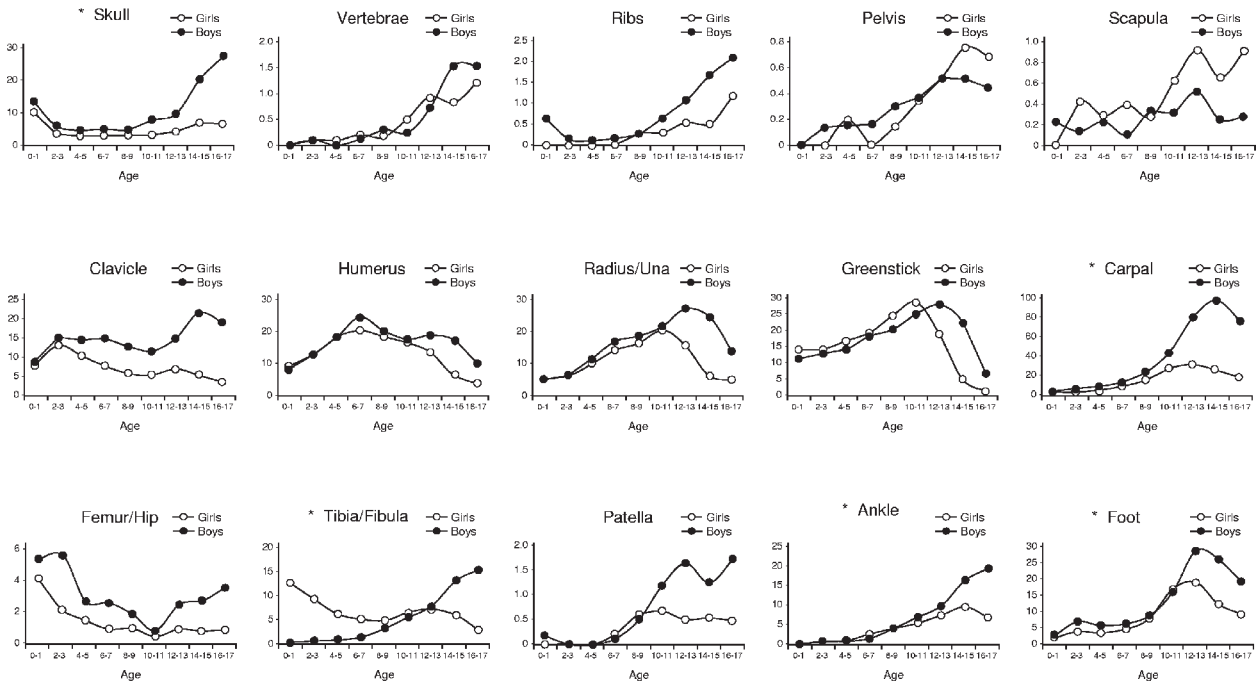

FIG. 2. Age- and sex-specific incidence of fractures at selected sites, among boys and girls (to age 17 years) registered in the General Practice Research Database, 1988 to 1998. The figure provides rates per 10,000 person-years, except where indicated.

TABLE 2. DISTRIBUTION ACROSS REGION OF THE INCIDENCE RATE STANDARDIZED TO THE UK POPULATION

Region	*No. of practices**	*No. of cases*	*Mean age of cases*	*Percent boys of cases*	*Mean duration follow-up (years)*	*Rate per 10000*	*Relative risk (95% CI)*
Scotland	30	3,477	9.8	63.5%	5.7	153.0	1.49 (1.43–1.56)
Northern and Yorkshire (Cumbria, Northumberland, Yorkshire [except South], Durham)	58	8,145	9.8	62.9%	6.6	155.8	1.51 (1.46–1.56)
North West (Cheshire, Lancashire)	103	12,190	9.7	62.4%	6.2	145.0	1.41 (1.37–1.45)
Northern Ireland	16	2,537	9.7	62.5%	6.3	169.2	1.66 (1.58–1.74)
West Midlands (Warwickshire, Staffordshire, Shropshire, Worcestershire, Hertfordshire)	77	9,857	9.8	61.9%	6.4	123.2	1.20 (1.16–1.24)
Trent (Leicestershire, Nottingham, Derbyshire, Lincolnshire, South Yorkshire)	65	9,224	9.9	62.6%	6.4	145.3	1.41 (1.37–1.46)
Eastern (Cambridgeshire, Suffolk, Norfolk, Essex, Bedfordshire, Hertfordshire)	77	11,247	9.9	62.5%	5.9	128.4	1.25 (1.21–1.29)
Wales	41	5,147	9.9	63.5%	6.4	163.1	1.60 (1.54–1.66)
South West (Cornwall, Devon, Dorset, Gloucestershire, Somerset)	70	9,388	9.9	62.0%	6.2	131.0	1.27 (1.23–1.32)
Greater London	78	6,219	9.7	63.0%	5.8	105.4	1.02 (0.98–1.05)
South East (Berkshire, Surrey, Sussex, Kent, Hampshire, Oxfordshire, Buckinghamshire, Northamptonshire)	66	6,696	9.7	62.7%	6.3	103.5	References

*Information on region was not available for one practice.

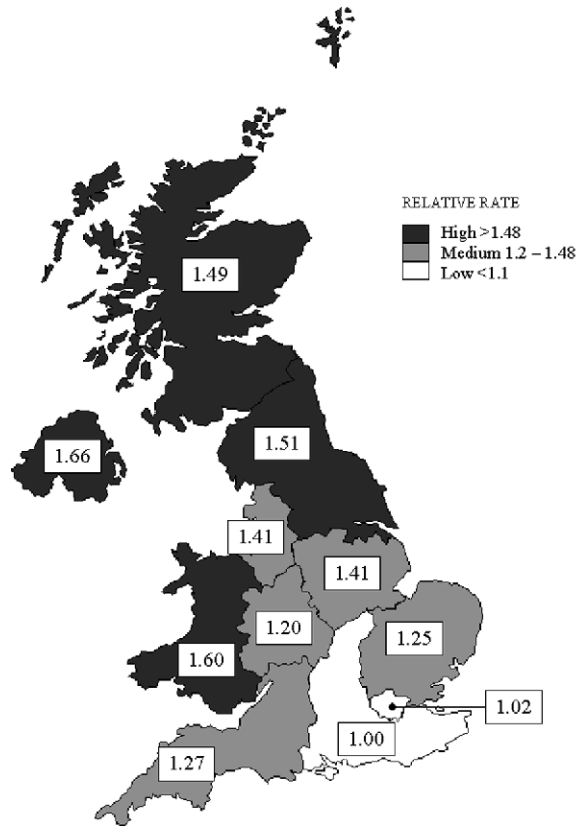

FIG. 3. Geographic variations in the age- and sex-adjusted incidence of fractures at any skeletal site among children (to age 17 years) in the United Kingdom. The figure provides relative rates for fracture in 11 geographic regions, with the southeast region as the reference value.

fractures of the humeral shaft in 249 patients, including 17 patients 12–20 years of age, but no further age breakdown was provided. Therefore, comparisons with published data are difficult. Other studies that include data from the United Kingdom date back to the 1950s.[14]

The incidence patterns for all childhood fractures are similar to those described in previous studies from Scandinavia and the United States. Incidence rates are greater among boys than among girls, with the peak age of occurrence earlier in girls (11 years) than among boys (14 years). Although investigation of the risk factors that might explain this pattern have focused on the importance of low- and high-energy trauma, recent clinical studies have suggested that children with distal forearm fractures have lower areal and volumetric BMD than age- and sex-matched controls without fracture.[15] Indeed, work over two decades ago by Landin and Nilsson[16] showed that forearm BMC was significantly reduced among children in whom fractures were caused by low-energy trauma compared with healthy age-matched children. In contrast, there was no significant difference in BMC between children sustaining fractures after high-energy trauma and controls. The gender-specific incidence patterns might also reflect a contribution from bone fragility: the peak age of fracture occurrence in boys and girls is remarkably close to the age at which the discordance between height gain and the accrual of volumetric BMD is most pronounced.[17] The third observation supporting a role for bone fragility in childhood fracture is the steep increase in age- and sex-specific incidence observed in Scandinavia between 1950 and 1979.[1,18]

Our study provides robust enough estimates of fracture incidence at different sites to explore heterogeneity in incidence patterns. Fractures at the wrist, hand, foot, ankle, rib, and patella reveal a similar pattern, with rates rising faster among boys than girls and separation between the gender-specific peaks around the time of puberty. They contrast markedly with the less frequently involved sites (humerus, hip, tibia/fibula, skull, clavicle, and scapula), which show more stable or even declining rates with advancing age. It may be that, as with fractures in later life, skeletal fragility plays a greater role in the pathogenesis of fractures at certain sites.

To our knowledge, data on the geographic variation in childhood fracture incidence within this country have not been previously reported. Our results suggest considerable differences in the rates observed in different British regions, after allowance is made for differences in the age and sex structure of the population. Of particular interest are the almost 50% higher rates observed in Northern Ireland, Scotland, Wales, and north England compared with London and southeast England. Differences in case ascertainment would seem an unlikely explanation for these findings, which are based on numerous general practices in each region. Although they might reflect a contribution of socioeconomic status to fracture risk (and accidents as a whole are known to be highly correlated with social class[19]), it is fascinating that the geographic pattern maps well to regional variation in hip fracture incidence in England and Wales.

An important limitation of our study is the classification of fracture site imposed by the coding system used by the GPRD. This uses the individual bone sustaining the fracture (e.g., radius) rather than the anatomical location (e.g., wrist). It was therefore not easy to characterize the epidemiology of fractures in particular areas within a bone, such as the diaphyseal, supracondylar, or trochanteric regions of the femur. In addition, data on fractures of the ribs and skull are likely to be less accurate than in surveys based in a single hospital because of variation in the use of radiographic evaluation among children who sustain moderate or minor degrees of trauma. Nevertheless, our incidence estimates were comparable with those observed in the previously described Swedish study,[1] as well as with those of a more recent incidence study of childhood distal forearm fracture in Rochester, MN.[20] In the latter, age- and sex-adjusted rates of distal forearm fracture in 1999–2001 were found to be 372.9/100,000 py, a figure extremely close to our estimate of 393/100,000 py for radius/ulna fractures.

In conclusion, we present a population-based epidemiological study of childhood fractures in the United Kingdom. Our results suggest that such fractures are a common problem, with around one-third of boys and girls sustaining at least one fracture before 17 years of age. Rates are higher among boys than girls, and male incidence rates peak later than those among females. Indeed, at this age, the incidence of childhood fractures (3%

among boys and 1.5% among girls) is only surpassed at 85 years of age among women and never among men. The most common site affected in both sexes is the radius/ulna (almost 30%), closely followed by the small bones of the hand and wrist. Finally, there is pronounced geographic variation in childhood fracture incidence within this country. Urgent studies to clarify the pathogenesis of these fractures are now required. If they are indeed associated with fractures in later life, particularly among women, they comprise a sufficiently frequent occurrence around which secondary preventive strategies could be based.

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REFERENCES

1. Landin LA 1983 Fracture patterns in children. Acta Orthop Scand Suppl **54:**1–109.
2. Houshian S, Mehdi B, Larsen MS 2001 The epidemiology of elbow fracture in children: Analysis of 355 fractures, with special reference to supracondylar humerus fractures. J Orthop Science **6:**312–315.
3. Hinton RY, Lincoln A, Crockett MM, Sponseller P, Smith G 1999 Fractures of the femoral shaft in children. Incidence, mechanisms, and sociodemographic risk factors. Patient Care Manage **81:**500–509.
4. Walley T, Mantgani A 1997 The UK general practice research database. Lancet **350:**1097–1099.
5. Jick H, Jick SS, Derby LE 1991 Validation of information recorded on general practitioner based computerised data resource in the United Kingdom. BMJ **302:**766–768.
6. van Staa TP, Abenhaim L 1994 The quality of information recorded on a UK database of primary care records: A study of hospitalization due to hypoglycaemia and other conditions. Pharmacoepidemiol Drug Saf **3:**15–21.
7. van Staa TP, Abehaim L, Cooper C, Begaud B, Zhang B, Leufkens HGM 2000 The use of a large pharmaco-epidemiological database to study exposure to oral corticosteroids and risk of fractures: Validation of study population and results. Pharmacoepidemiol Drug Saf **9:**359–366.
8. van Staa TP, Cooper C, Leufkens HGM, Bishop N 2003 Children and the risk of fractures caused by oral corticosteroids. J Bone Miner Res **18:**913–918.
9. Larsen CF, Brondum V, Skov O 1992 Epidemiology of scaphoid fractures in Odense, Denmark. Acta Orthop Scand **63:**216–218.
10. Horak J, Nilsson BE 1975 Epidemiology of fracture of the upper end of the humerus. Clin Orthop **112:**250–253.
11. Jensen SL, Andresen BK, Mencke S, Nielsen PT 1998 Epidemiology of ankle fractures. Acta Orthop Scand **69:**48–50.
12. Emami A, Mjoberg B, Ragnarsson B, Larsson S 1996 Changing epidemiology of tibial shaft fractures. Acta Orthop Scand **67:**557–561.
13. Tytherleigh-Strong G, Walls N, McQueen MM 1998 The epidemiology of humeral shaft fractures. J Bone Joint Surg Br **80:**249–253.
14. Buhr AJ, Cooke AM 1959 Fracture patterns. Lancet **1:**531–536.
15. Jones IE, Taylor RW, Williams SM, Manning PJ, Goulding A 2002 Four-year gain in bone mineral in girls with and without past forearm fractures: A DXA study. Dual energy X-ray absorptiometry. J Bone Miner Res **17:**1065–1072.
16. Landin L, Nilsson BE 1983 Bone mineral content in children with fractures. Clin Orthop **178:**292–296.
17. Rizzoli R, Bonjour J-P, Ferrari SL 2001 Osteoporosis, genetics and hormones. J Mol Endocrinol **26:**79–94.
18. Rockwood CA Jr, Wilkins KE 2001 The present status of children's fractures. In: Bealy JH, Kassem JR (eds.) Fractures in Children, 5th ed. Lippincott Williams & Wilkins, New York, NY, USA, pp. 6–19.
19. Acheson D 1998 Independent Inquiry Into Inequalities in Health Report. The Stationery Office, London, UK.
20. Khosla S, Melton LJ III, Dekutoski MB, Achenbach SJ, Oberg AL, Riggs DL 2003 Incidence of childhood distal forearm fractures over 30 years: A population-based study. JAMA **290:**1479–1485.

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