Risk factors for long-bone fractures in children up to 5 years of age: a nested case–control study

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ABSTRACT

Aim To investigate risk factors for first long-bone fractures in children up to 5 years old in order to provide evidence about which families could benefit from injury prevention interventions.

Methods Population-based matched nested case–control study using The Health Improvement Network, a UK primary care research database, 1988–2004. Maternal, household and child risk factors for injury were assessed among 2456 children with long-bone fractures (cases). 23 661controls were matched to cases on general practice. Adjusted ORs and 95% CIs were estimated using conditional logistic regression.

Results Fractures of long-bones were independently associated with younger maternal age and higher birth order, with children who were the fourth-born in the family, or later, having a threefold greater odds of fracture compared to first-born children (adjusted OR 3.12, 95% CI 2.08 to 4.68). Children over the age of 1 year had a fourfold (13–24 months, adjusted OR 4.09 95% CI 3.51 to 4.76) to fivefold (37+ months, adjusted OR 4.88 95% CI 4.21 to 5.66) increase in the odds of a long-bone fracture compared to children aged 0–12 months. Children in families with a history of maternal alcohol misuse had a raised odds of long-bone fracture (adjusted OR 2.33, 95% CI 1.13 to 4.82) compared to those with no documented history.

Conclusions Risk factors for long-bone fractures in children less than 5 years old included age above 1 year, increasing birth order, younger maternal age and maternal alcohol misuse. These risk factors should be used to prioritise families and communities for injury prevention interventions.

What is already known on this topic

- Long-bone fractures are an important preventable cause of childhood morbidity, disability and hospital attendance.
- Children aged 0–5 are at particular risk of injuries in the home.
- National Institute for Health and Care Excellence (NICE) guidelines recommend the identification of children at high risk of injuries in order to target them with preventative interventions, such as home safety assessments.

What this study adds

- Risk factors for long-bone fractures, a population-level indicator of more severe injury, were similar to those identified in previous injury studies of all fracture types.
- Information recorded in primary care can be used to identify families that should be prioritised for evidence based injury prevention interventions.

INTRODUCTION

Injuries in childhood are an important preventable cause of morbidity and mortality, leading to approximately 2 million emergency department (ED) attendances and 120 000 hospital admissions each year among children aged 1–14 in the UK.[1] Fractures are an important injury as nearly all lead to ED attendance, with some cases requiring hospital admission, or an operative procedure. The anatomical site and severity of a fracture are important in terms of treatment required, risk of complications and functional outcome.[2 3] Long-bone fractures occurring in the femur, tibia, fibula, humerus, radius or ulna, have been used at a population level as an indicator of more severe injuries.[4]

Guidance by the National Institute for Health and Care Excellence (NICE) recommends the identification of households with children at greatest risk of injury in order to target preventative interventions, such as home safety assessments and safety equipment provision.[5] Injuries among children less than 5 years old most commonly occur within the home,[5 6] with fractures most commonly resulting from falls.[7] Among young children, intentional injury is also an important cause of fractures, potentially accounting for up to 25% of fractures in children less than 12 months.[7 8] Understanding risk factors for long-bone fractures can help preventative efforts to be targeted towards these more severe injuries.

Existing studies have demonstrated that child age, sex, deprivation, household size, maternal age and birth order influence fracture risk.[6 9–18] However, few have assessed risk factors for long-bone fractures. We therefore aimed to investigate risk factors for long-bone fractures in children less than 5 years old using a large UK primary care database.

METHODS

Participants and setting

We used data from The Health Improvement Network (THIN), a longitudinal primary care database containing anonymised medical, prescribing

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and lifestyle data for patients registered with participating UK general practices. At the time the dataset was generated, THIN held data on 3.9 million patients registered across 255 general practices. Information from secondary care is received by GPs and recorded in patient records. Data are recorded in THIN using Read codes, a clinical terminology system based on the International Classification of Diseases V.10 (ICD-10).

Study participants were drawn from an open cohort of 180 064 children in THIN who were born between January 1988 and September 2004 and whose primary care records had been linked to their mothers' primary care records, as previously described.[19] Children had to have been registered at the general practice within 60 days of birth to maximise the likelihood of capturing their first fracture event. Cases and controls were a subset of children from a previous case–control study assessing risk factors for poisonings, burns and fractures.[13] Fracture cases were children less than 5–years old who had a first fracture event in their medical record. For every case, up to 10 controls were selected at random. Controls were matched to cases on general practice and were children less than 5 years old who had not had a fracture before or on the injury date of their matched case. Children were not matched by age and sex to enable exploration of the effects of these variables.

Definition of long-bone fracture cases

From the case–control population described above, we identified long-bone fracture cases using Read codes referring to fractures, as classified by ICD-10, of the femur (S72.0–S72.9, T93.1), humerus (S42.2–S42.4, S42.7), ulna and/or radius (S52.0–S52.9) and tibia and/or fibula (S82.1–82.9). Less specific Read codes such as 'broken arm' and 'greenstick fracture' were included in the definition as it was likely these codes indicated a long-bone fracture. As some Read codes do not specify an anatomical site (eg, 'fracture not otherwise specified'), we examined Read codes entered within 3 months of the first fracture Read code, to identify if the fracture had occurred in a long-bone. Three months was chosen through examining the distribution of Read codes entered onto the medical record, and to allow time for additional information from secondary care to be entered into the medical record.

Risk factor variables

Potential child, maternal and household risk factors for fractures were identified from existing literature.[6 9–18] Those available in THIN included child age, sex and birth order. Maternal risk factors included age at delivery, smoking status and perinatal depression (a diagnosis of depression during pregnancy or within 6 months of delivery). Mothers were classified as having a history of alcohol misuse if they had a Read code indicating harmful or hazardous drinking documented in their medical record before the fracture event. Household risk factors included the number of children in the household (those aged 16 or under) and socioeconomic status measured using quintiles of the Townsend index of material deprivation,[20] representing relative socioeconomic position at a national level.

Statistical analyses

We estimated unadjusted and adjusted ORs and 95% CIs for the association of long-bone fracture with each risk factor using conditional logistic regression models. Backward elimination, as described by Collett,[21] was used to build the multivariable models, with likelihood ratio tests (LRTs) used to assess significance and $p<0.05$ considered statistically significant. Child age and sex were included in all models. We included the whole study population in all multivariable models to ensure comparability. To account for missing maternal smoking and Townsend quintile data, we included a missing data category for these variables in the regression models. Potential interactions, based on theoretical plausibility, were assessed by adding interaction terms to models and testing their significance using LRTs, with $p<0.01$ considered significant (due to large study size). We tested for multicollinearity using the covariate correlation matrix and by calculating the variance inflation factor. Analyses were carried out in Stata V.10.1.

Statistical power was calculated using the prevalence of the rarest risk factor, recording of alcohol misuse within the same primary care population (0.48%).[22] To obtain 80% power to detect an OR of 2.2 at the 5% significance level, using a correlation coefficient of 0.2 to allow for matching by general practice,[23] 2019 cases with 10 matched controls per case were required. For all other risk factors of higher prevalence there was a greater level of power.

As fracture Read codes varied from those that were highly specific in defining the anatomical site of fracture to less specific codes such as 'broken arm' and 'greenstick fracture', misclassification of the outcome could have been introduced by including Read codes where there was uncertainty about the anatomical site of fracture. We therefore carried out two sensitivity analyses (table 1), first excluding fractures where only a

Table 1 Sensitivity analysis, definitions of long-bone fractures (ICD-10 codes)

	Codes used to define long-bone fractures
Sensitivity analysis 1: Exclusion of fractures where only a 'greenstick fracture' Read code was used.	Humerus: S42.2, S42.3, S42.4, S42.7
	Ulna and/or radius: S52.–S52.9
	Femur: S72.0–S72.9, T93.1
	Tibia and/or fibula: S82.1–82.9
	T10 ('broken arm')
	T12 ('broken leg')
	T02.2–6 (fractures involving multiple regions of limbs)
	T93.2 (sequelae of other fractures of lower limb)
	T92.1 (sequelae of fracture of arm)
Sensitivity analysis 2: Definition restricted to the most specific codes	Humerus: S42.2, S42.3, S42.4, S42.7
	Ulna and/or radius: S52.–S52.9
	Femur: S72.0–S72.9, T93.1
	Tibia and/or fibula: S82.1–82.9

Table 2 Characteristics of study participants and associations of risk factors with long-bone fractures

Covariate	Cases n=2456 Frequency (%)	Controls n=23 661 Frequency (%)	Unadjusted OR (95% CI)	Adjusted OR (95% CI)*
Child covariates				
Sex of child				
Female	1196 (48.7)	11 450 (48.4)	1.0	1.00
Male	1260 (51.3)	12 211 (51.6)	0.99 (0.91 to 1.08)	0.99 (0.91 to 1.08)
Age of child				
0–12 months	248 (10.1)	7795 (32.9)	1.0	1.00
13–24 months	660 (26.9)	5124 (21.7)	4.12 (3.54 to 4.80)	4.09 (3.51 to 4.76)
25–36 months	612 (24.9)	4178 (17.7)	4.84 (4.15 to 5.65)	4.82 (4.13 to 5.63)
37+ months	936 (38.1)	6564 (27.7)	4.78 (4.13 to 5.54)	4.88 (4.21 to 5.66)
Birth order of child				
1st born	1499 (61.0)	16 648 (70.4)	1.0	1.00
2nd born	776 (31.6)	5947 (25.1)	1.49 (1.35 to 1.63)	1.52 (1.38 to 1.68)
3rd born	149 (6.1)	927 (3.9)	1.86 (1.55 to 2.24)	1.94 (1.60 to 2.35)
4th born or more	32 (1.3)	139 (0.6)	2.76 (1.86 to 4.08)	3.12 (2.08 to 4.68)
Singleton	2406 (98.0)	23 269 (98.3)	1.0	–
Multiple deliveries	50 (2.0)	392 (1.7)	1.23 (0.92 to 1.66)	
Maternal covariates				
Maternal age at birth of child				
<20 years	132 (5.4)	1281 (5.4)	1.02 (0.84 to 1.24)	1.31 (1.07 to 1.59)
20–29 years	1234 (50.2)	11 467 (48.5)	1.07 (0.98 to 1.17)	1.10 (1.00 to 1.20)
30+ years	1090 (44.4)	10 913 (46.1)	1.0	1.00
Perinatal depression				
No	2281 (92.9)	22 142 (93.6)	1.0	–
Yes	175 (7.1)	1519 (6.4)	1.12 (0.95 to 1.32)	
Maternal smoking				
Non-smoker	1268 (51.6)	11 936 (50.4)	1.0	–
Ex-smoker	115 (4.7)	1170 (4.9)	0.93 (0.76 to 1.13)	
Current smoker	534 (21.7)	5307 (22.4)	0.94 (0.84 to 1.05)	
Missing	539 (22.0)	5248 (22.2)	0.95 (0.85 to 1.07)	
Maternal alcohol misuse				
No	2446 (99.6)	23 625 (99.8)	1.0	1.00
Yes	10 (0.4)	36 (0.2)	2.61 (1.30 to 5.27)	2.33 (1.13 to 4.82)
Household covariates				
Household Townsend index quintile				
1 (least deprived)	577 (23.5)	5654 (23.9)	1.0	–
2	451 (18.4)	4442 (18.8)	0.99 (0.87 to 1.13)	
3	440 (17.9)	4354 (18.4)	0.99 (0.86 to 1.14)	
4	461 (18.7)	4207 (17.8)	1.08 (0.94 to 1.24)	
5 (most deprived)	368 (15.0)	3392 (14.3)	1.05 (0.90 to 1.23)	
Missing	159 (6.5)	1612 (6.8)	0.86 (0.63 to 1.16)	
Single parenthood				
Single adult	984 (40.1)	9167 (38.7)	1.0	–
2 adults	1265 (51.5)	12 274 (51.9)	0.97 (0.88 to 1.06)	
Other	207 (8.4)	2220 (9.4)	0.87 (0.74 to 1.03)	
Number of children under 16 living in the household				
1 child	1433 (58.4)	13 820 (58.4)	1.0	–
2 children	662 (27.0)	6593 (27.9)	0.97 (0.88 to 1.07)	
3 or more children	361 (14.7)	3248 (13.7)	1.08 (0.95 to 1.22)	

*Model mutually adjusted for all variables where ORs are given.

'greenstick fracture' Read code was used, and second, restricting the definition to the most precise Read codes for long-bone fractures.

Ethics statement

Approval for this study was granted in October 2009 by the THIN Scientific Review Committee.

RESULTS

Table 2 shows the characteristics of the 2456 long-bone fracture cases and 23 661 controls, unadjusted ORs and risk factors identified as significant in the adjusted multivariable model. Of the cases, 1260 (51%) were male and 1196 (49%) were female, with similar proportions of males and females among the controls. Cases were generally older than controls; 38% of cases were 37 months or older, compared to 28% of controls.

In multivariable analysis, child sex was not associated with risk of long-bone fracture (OR 0.99, 95% CI 0.91 to 1.08). Children over the age of 1 year had a fourfold (13–24 months, OR 4.09 95% CI 3.51 to 4.76) to fivefold (37+ months, OR 4.88 95% CI 4.21 to 5.66) increase in the odds of a long-bone fracture compared to children aged 0–12 months. Children of mothers aged less than 20 had a raised odds of long-bone fracture compared to those with mothers aged 30 and over (OR 1.31, 95% CI 1.07 to 1.59). The odds of fracture increased with increasing birth order (test for trend $p<0.0001$), with fourth or more born children having a threefold greater odds of long-bone fracture than first-born children (OR 3.12, 95% CI 2.08 to 4.68). Children whose mother had a history of alcohol misuse recorded on the medical record had a twofold higher odds of long-bone fracture (OR 2.33, 95% CI 1.13 to 4.82) compared to those without a record of alcohol misuse.

Table 3 presents the sensitivity analysis used to assess the impact of varying the definition of long-bone fractures. Findings were robust to excluding greenstick fractures, and restricting the definition to the most specific Read codes. No statistically significant interactions were found between risk factors, and no evidence of multicollinearity was identified in the final regression model.

DISCUSSION

Our study has shown that long-bone fractures were independently associated with child age over 12 months, younger maternal age, increasing birth order and maternal alcohol misuse. Importantly, we have shown that these risk factors are apparent in a large, general population cohort identified through electronic primary care medical systems; demonstrating the usefulness of primary care data for the identification of families at higher injury risk.

Strengths and limitations

The main strengths of our study are the large study size and that risk factors were prospectively recorded on the medical record before the fracture event. We matched cases and controls on general practice, accounting for differences in data recording between practices and over time. Data held in THIN are representative of the UK population in terms of age, sex and geographical coverage,[24] and although there is yet to be a study assessing the ethnic breakdown of THIN, a study using a similar database found an ethnic breakdown similar to the 2011 Census.[25] Our findings are therefore likely to be generalisable to the UK population.

Data in THIN are however not primarily collected for research purposes and so we were unable to assess injury mechanism (eg, falls from heights), location (eg, home) or intent (eg, maltreatment) as these data are poorly recorded in primary care, and in some cases injury intent may be clinically misdiagnosed. Fractures resulting from intentional harm predominantly occur in children less than 18 months,[8] with the proportion of such fractures varying widely; estimated as 11–56% of fractures in children less than 12 months.[26] By including some fractures resulting from intentional harm, we may have overestimated the effect of risk factors such as maternal alcohol misuse that have previously been associated with intentional injuries.[27] The impact of this should however be relatively small as only 10% of fractures in this study occurred in those less than 12 months, and only a proportion of these are likely to have resulted from intentional injury.

The recorded prevalence of alcohol misuse was lower within our dataset than identified through other sources,[28] and as we did not explore the effect of other drinking patterns (eg, binge drinking), the overall impact of maternal alcohol consumption may be greater than we have estimated. In addition, we have not

Table 3 Sensitivity analysis, varying the definition of long-bone fractures

Variable	Long-bone fractures: Broadest definition of long-bone fracture used for the main analysis (n=2456) Adjusted OR (95% CI)	Sensitivity analysis 1: Excluding greenstick fractures (n=2095) Adjusted OR (95% CI)	Sensitivity analysis 2: Definition of long-bone fractures restricted to the most specific Read codes (n=1878) Adjusted OR (95% CI)
Child variables			
Sex of child			
Female	1.00	1.00	1.00
Male	0.99 (0.91 to 1.08)	1.04 (0.95 to 1.14)	1.04 (0.95 to 1.15)
Age of child			
0–12 months	1.00	1.00	1.00
13–24 months	4.09 (3.51 to 4.76)	3.99 (3.39 to 4.70)	4.13 (3.47 to 4.92)
25–36 months	4.82 (4.13 to 5.63)	4.76 (4.03 to 5.62)	4.90 (4.10 to 5.85)
37+ months	4.88 (4.21 to 5.66)	4.76 (4.06 to 5.58)	4.88 (4.12 to 5.78)
Birth order of child			
1st	1.00	1.00	1.00
2nd	1.52 (1.38 to 1.68)	1.52 (1.37 to 1.69)	1.50 (1.34 to 1.67)
3rd	1.94 (1.60 to 2.35)	2.01 (1.64 to 2.47)	1.93 (1.55 to 2.41)
4th or more	3.12 (2.08 to 4.68)	3.19 (2.03 to 5.02)	2.99 (1.83 to 4.88)
Maternal variables			
Maternal age			
<20 years	1.31 (1.07 to 1.59)	1.37 (1.11 to 1.69)	1.38 (1.10 to 1.73)
20–29 years	1.10 (1.00 to 1.20)	1.10 (1.00 to 1.22)	1.10 (0.99 to 1.22)
30+ years	1.00	1.00	1.00
Maternal alcohol misuse			
No	1.00	1.00	1.00
Yes	2.33 (1.13 to 4.82)	2.39 (1.11 to 5.11)	2.94 (1.34 to 6.46)

adjusted for some potential risk factors, such as ethnicity, which was poorly recorded in primary care during the study time period,[29] preterm birth, and rare medical conditions that can predispose children to fractures (eg, osteogenesis imperfecta).[8] We were also unable to assess paternal risk factors for injury, as it is difficult to accurately identify fathers within primary care data.

We may not have identified some long-bone fracture cases if GPs did not receive correspondence about ED attendances or hospital admissions, a Read code was not entered in the medical record, or a code was used that did not specify the anatomical site of fracture. We however attempted to maximise our case ascertainment by using a broad definition of long-bone fractures. This is unlikely to have biased our findings, as even when using the most specific long-bone fracture definition in our sensitivity analysis, the findings were similar. Any under-ascertainment of long-bone fractures, unless associated with child, maternal or household risk factors, would be likely to underestimate observed associations in this study.

Comparison to existing literature

Our finding of a marked increase in the odds of fracture among children over 12 months is consistent with previous studies;[9 13 17] and is likely to reflect developmental changes and the commencement of walking.[30] Similar to previous injury studies,[31 32] we found an increased odds of long-bone fracture with higher birth order. We did not however find an association with the number of children in the household, indicating that birth order, which gives information about the relationships between children, may be more important than the general number of children in the household. Mechanisms for this association could include reduced parental supervision due to more children being in the household, activities or games children are exposed to through having older siblings, and older children being responsible for supervising younger siblings.[32]

Evidence on associations between socioeconomic status and childhood fractures is conflicting. Similar to two studies,[12 13] we found no association between the odds of fracture and socioeconomic status. Comparatively, a cross-sectional study by Hippisley-Cox *et al*[18] found that children from the most deprived areas were more likely to be both hospitalised and have an operation for a long-bone fracture than children from the most affluent areas. Our findings may differ, as we included all long-bone fractures and not just hospitalised cases, and we focused on first fracture events. Previous studies have demonstrated that children sustaining recurrent injuries are more likely to have social risk factors (eg, family violence),[33 34] and so the lack of association in our study could be explained by our focus on first fracture events.

To our knowledge, few studies have assessed the impact of maternal alcohol misuse on childhood fractures; although there are studies of other injury types where an association has been found.[22 35] Associations between maternal alcohol misuse and childhood injuries could relate to alcohol influencing supervisory practices, the presence of hazards or the uptake of injury prevention practices; although our interpretation is limited by not having data on mothers' alcohol consumption at the time of the fracture.

Implications for practice and research

Preventing childhood injuries requires multiagency action that includes a range of measures from education to environmental modification and legislation. Among preschool children, over two-thirds of injuries occur within the home environment,[36] and so clinicians such as GPs, health visitors and paediatricians can, where appropriate, refer high risk families to home safety assessment and equipment schemes in accordance with NICE guidelines on preventing injuries.[5] It is also important that parents are made aware of key developmental stages and the associated injury risks, so that they can anticipate potential hazards. Within primary care, brief alcohol interventions have been shown as effective,[37] with growing evidence to support family focused interventions.[38] While further research on associations between childhood fractures and maternal alcohol misuse would be beneficial, interventions to reduce maternal alcohol consumption could improve the health of the mother, alongside potentially reducing childhood injuries. At a population level, public health teams should prioritise interventions to communities where children are at the greatest risk of injury. From our study, households with younger mothers, multiple older siblings and where mothers misuse alcohol should be prioritised. Future research could assess how these risk factors change among children who sustain repeated long-bone fractures or fractures at other sites indicating severe injury (eg, skull fracture), and, with recent linkage of primary and secondary care data, gain more information on injury intent and mechanisms.[39]

Contributors DK, EO and LJT designed the study. EO and RB developed Read codes for defining long-bone fractures. LJT developed the mother–child linked cohort and extracted the nested case–control dataset for fractures. RB conducted all data analyses and drafted the initial manuscript. All authors contributed to the interpretation of the findings and the writing of the manuscript.

Competing interests None.

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Data sharing statement A list of fracture Read codes is available on request.

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