Risk of Recurrent Fracture: A Population-Based Study
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OBJECTIVES: To determine if children who sustain a fracture in childhood had an increased rate of fracture later in childhood or early adulthood. The a priori null hypothesis was that children who sustained a fracture would not have an increased rate of future fractures compared with children who did not sustain a fracture when controlling for important covariates.

METHODS: This is a population-based retrospective cohort study using health care databases in Ontario. Approximately 2.5 million healthy children aged 0 to 15 years living in Ontario, Canada between April 1, 2003, and March 31, 2004, were included and followed for 7 years. The exposure was occurrence of any fracture during a 1-year baseline period. The main outcome was any fractures during a 7-year follow-up period.

RESULTS: A total of 43,154 children suffered a fracture during the baseline year (17.5 fractures per 1000 child years). Children with a baseline fracture had a 60% higher rate of fracture (incidence rate ratio: 1.60; 95% confidence interval: 1.46–1.75; P < .0001) during the follow-up period after adjustment for sex, rurality, history of previous fracture, and the occurrence of other injuries (head and soft-tissue).

CONCLUSIONS: The occurrence of a fracture during childhood was associated with an increased rate of future fractures compared with children who did not suffer a fracture. Attempting to improve childhood bone health by targeting children who present to a fracture clinic with multiple fracture risk factors may be a useful strategy for secondary prevention of fractures and may have beneficial effects on long-term bone health.

WHAT’S KNOWN ON THIS SUBJECT: Childhood fractures are common, but understanding of clinical risk factors for childhood fractures remains limited. The occurrence of a fracture as a risk factor for future fractures has not been assessed in the pediatric population at the population level.

WHAT THIS STUDY ADDS: The occurrence of a fracture during childhood was associated with an increased rate of future fractures compared with children who did not suffer a fracture and may be used to target children for bone health evaluation and treatment.
Fractures are a common occurrence in childhood, with approximately one-half of boys and one-third of girls expected to suffer a fracture during childhood.8,14 Despite their common occurrence, there was little published literature describing the incidence and pattern of fractures in children until the 1980s.1 Numerous cross-sectional population-based studies have since been published from regions including Great Britain,2 Scotland,3 Wales,4,5 Norway,5–7 Finland,5,8 South Africa,9 Greece,10 and Estonia,11 with a threefold variation in the reported overall annual incidence of childhood fractures ranging from 12 to 36 fractures per 1000 child years.5,10

Upper-extremity fractures cause activity restriction in 72% of children (averaging 14 days), and lower-extremity fractures cause activity restriction in 84% of children (averaging 26 days).7 This places a burden on families and caregivers. Long-term disability or functional loss can follow childhood fracture but is poorly measured. The burden on the health care system in Ontario, Canada from childhood fractures includes 985 emergency department (ED) visits, 38 outpatient operations, and 69 inpatient operations per 100 000 children per year.12 Pediatric fractures from falls cost Canadian governments $1.2 billion dollars per year in direct and indirect costs.13

Several authors have identified a worrying trend of rising rates of childhood fractures after low-energy falls, specifically fractures of the distal radius and proximal humerus.8,14–17 These authors all voiced concerns that rising rates of low-energy fractures may be related to suboptimal bone health in childhood due to declining activity levels, worsening nutrition, or rising rates of childhood obesity.8,16,18 One author16 theorized that this phenomenon may portend a larger public health issue because the majority of bone development occurs during childhood and worsening childhood bone health may lead to an increase in rates of osteoporosis in later life. Authors of 2 retrospective studies have evaluated similar theories and identified long-term fracture risk related to childhood growth impairment19 and childhood malnutrition related to famine.20 Osteoporosis currently affects >75 million people in the United States, Europe, and Japan and causes >8.9 million fractures worldwide annually, leading to significant morbidity and mortality.21 It has become widely accepted that an elderly individual who suffers a low-energy fracture is at a significantly increased risk of suffering another fracture later in life.22 The osteoporotic fracture is a sentinel event that identifies that individual as having mechanically deficient bone. If a child has suboptimal bone health then they, too, should be at greater risk of fracture compared with similar children with optimal bone health. Authors of 2 publications to date have prospectively evaluated longitudinal fracture patterns in birth cohorts and found an increased risk of fracture after a first fracture in childhood.9,23 The study samples were small, preventing generalization at the population level, but the results raise concerns that fractures could indeed be independent predictors of future fractures in childhood, warranting additional study.

Risk factors identified by clinicians during the assessment of a child who presents with a fracture may ultimately assist with secondary prevention of pediatric fractures.

Did Ontario children who experienced a baseline fracture between April 1, 2003, and March 31, 2004 (fiscal year 2003 to 2004), experience a greater rate of future fractures than children who did not suffer a baseline fracture during the same time period? The a priori null hypothesis was that children who sustain a fracture would not have an increased rate of future fractures compared with children who do not sustain a fracture after statistical adjustment for important covariates.

METHODS

Overview

This is a population-based retrospective cohort study in which multivariable Poisson regression was used. Ontario health administrative databases were used to measure the association between 1 fracture and future fractures in childhood and early adulthood when controlling for relevant demographic, socioeconomic, and clinical factors in a cohort of children <16 years of age. This project was approved by the institutional research ethics review boards of the Hospital for Sick Children and the University of Toronto (Toronto, Ontario, Canada).

Data Sources

In this study, we used health databases from Ontario, the most populous province in Canada with a population of 12.2 million during the baseline period of this study, of whom ~2.5 million were <16 years of age. We identified baseline and follow-up fracture events from all ED visits recorded using International Classification of Diseases, 10th Revision (ICD-10) diagnostic codes in the National Ambulatory Care Reporting System database. The National Ambulatory Care Reporting System database covers all ED visits in Ontario and has mandatory ICD diagnosis fields, and a data reabstraction study has revealed 87.2% accuracy in coding injury diagnoses when compared with the original charts.24 The Ontario Health Insurance Plan (OHIP) database was used to identify previous fracture events. Demographic and
socioeconomic information was obtained from the Registered Persons Database and the 2001 Census of Canada, respectively. These data sets were linked by using unique encoded identifiers and analyzed at the Institute for Clinical Evaluative Sciences. Diagnostic and demographic variables collected for this study revealed good validity in a previous chart reabstraction study.25

Study Population and Cohort Definition

The study population included all children <16 years of age living in the province of Ontario during a 1-year baseline period from April 1, 2003, to March 31, 2004. Children were excluded if their health administrative records included invalid data or if they had any ICD-10 diagnostic code indicating a comorbid medical condition known to be associated with an increased fracture risk, including osteogenesis imperfecta, occurrence of a pathologic fracture, low bone density, juvenile arthropathy, osteopathy of any cause, and child abuse or neglect. The main exposure (the occurrence of a fracture during the baseline period) was defined as a visit to an ED between April 1, 2003, and March 31, 2004, with a discharge diagnostic code representative of an acute fracture (ICD-10 codes are listed in Supplemental Table 2). A fracture event that occurred during the observation period within 3 months of another fracture at the same anatomic location was excluded because it may not represent a new fracture event but rather reinjury or morbidity related to the preceding fracture. Date of death from any cause during the follow-up period was identified by using the RPDB for the purposes of censoring in the survival analysis.

Covariates

Patient-level covariates, including age during the baseline year, sex, and rural residence, were collected to enhance the statistical analysis. Rural residence was defined as a residential postal code located within a town outside the commuting zone of larger urban centers (population \( \geq 10\,000 \)) as defined by Statistics Canada26 using measures of social and economic integration obtained through the Census of Canada. Previous fracture history was collected by using OHIP fracture fee codes during a 7-year look-back window before the baseline period and was dichotomized (yes versus no) for the final analysis.

Nonfracture injury events were collected during the follow-up period for use as predictors of fracture rate to adjust for a more active or injury-prone child. We counted soft-tissue injuries and head injuries. These were defined as an ED visit with an ICD-10 discharge diagnostic code representative of a soft-tissue injury (superficial injuries, open wounds, dislocations, contusions, sprains, and strains of joints and ligaments) or head injury and were similarly dichotomized for the final analysis.

Neighborhood-level covariates derived from the 2001 Census of Canada as indicators of socioeconomic status included the neighborhood income quintile and Ontario Marginalization Index (ON-Marg). The ON-Marg is a census- and geography-derived index composed of 4 domains (residential instability, material deprivation, ethnic concentration, and dependency) that was designed to reveal differences in social marginalization between geographic areas and understand inequalities in various measures of health and social well-being.27 Census-derived data were generated at the level of the dissemination area, small geographically defined units of \( \geq 1 \) block with a population of 400 to 700 persons, which is the smallest geographic area for which all census data are available.

Primary Statistical Analysis

To accommodate both the varying duration of observation and the possibility that 1 child could experience multiple fracture events during the follow-up period, we performed Poisson regression to generate unadjusted and adjusted incidence rate ratios (IRRs). Multivariable Poisson regression allowed adjustment for potential confounders, including patient demographic, socioeconomic, and clinical factors obtainable from the health administrative databases.

Variables of clinical interest (current fracture, sex, and rurality) were included in each multivariable model regardless of statistical significance. Additional predictors were added in order of importance (history of previous fracture, occurrence of soft-tissue injury, and occurrence of a head injury) by using a manual forward stepwise technique. The estimates and SE of the association between the main predictor of interest and the primary outcome were assessed after each addition, and optimal-model fit was assessed by using the negative log-likelihood statistic and the \( \chi^2 \) over-dispersion ratio. Preliminary analysis revealed a statistical interaction between age and several of the potential confounders, so the final analysis was stratified by age during the baseline period with results reported.
separately for each age stratum (by year). Incident rates are reported per 1000 child years. All statistical analysis was performed by using SAS version 9.2 (SAS Institute, Inc, Cary, NC) for Unix.

**Secondary Statistical Analysis**

Unadjusted Kaplan-Meier fracture-free survival curves were plotted, which allowed log-rank comparison of fracture-free survival within the baseline fracture and no baseline fracture cohorts.

**RESULTS**

Approximately 2.5 million Ontario children met the inclusion criteria for this study. A total of 43 154 children (1.75% of the cohort) suffered a fracture during the baseline period, placing them in the baseline fracture cohort. Demographic and socioeconomic characteristics of the cohort stratified by baseline fracture status are shown in Table 1. The cohort included slightly more boys (51.3%; \( n = 1.26 \) million) than girls (48.7%; \( n = 1.2 \) million), but the

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**TABLE 1 Description of Demographic and Socioeconomic Predictors in the Study Population Stratified by Baseline Fracture Status**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall, ( n ) (%)</th>
<th>Baseline Fracture, ( n ) (%)</th>
<th>No Baseline Fracture, ( n ) (%)</th>
<th>( P )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>2 462 564</td>
<td>43 154 (1.75)</td>
<td>2 419 410 (98.25)</td>
<td>—</td>
</tr>
<tr>
<td>Age at baseline, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–2</td>
<td>406 760 (16.52)</td>
<td>3137 (7.27)</td>
<td>403 623 (16.68)</td>
<td>—</td>
</tr>
<tr>
<td>3–5</td>
<td>433 793 (17.62)</td>
<td>5083 (11.80)</td>
<td>428 700 (17.72)</td>
<td>—</td>
</tr>
<tr>
<td>6–8</td>
<td>471 757 (19.16)</td>
<td>6891 (16.18)</td>
<td>464 776 (19.21)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>9–11</td>
<td>483 448 (20.04)</td>
<td>11 140 (25.81)</td>
<td>482 308 (19.93)</td>
<td>—</td>
</tr>
<tr>
<td>12–15</td>
<td>656 810 (26.67)</td>
<td>16 803 (38.94)</td>
<td>640 007 (26.45)</td>
<td>—</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1 200 464 (48.75)</td>
<td>15 555 (36.05)</td>
<td>1 184 909 (48.98)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Male</td>
<td>1 262 104 (51.25)</td>
<td>27 599 (63.95)</td>
<td>1 234 505 (51.02)</td>
<td>—</td>
</tr>
<tr>
<td>Rurality</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>2 133 004 (86.95)</td>
<td>35 986 (83.48)</td>
<td>2 097 018 (87.01)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Rural</td>
<td>320 083 (13.05)</td>
<td>7119 (16.52)</td>
<td>312 964 (12.99)</td>
<td>—</td>
</tr>
<tr>
<td>Previous fracture history</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>2 276 000 (92.42)</td>
<td>35 725 (82.78)</td>
<td>2 240 275 (92.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Yes</td>
<td>186 568 (7.58)</td>
<td>7429 (17.22)</td>
<td>179 139 (7.40)</td>
<td>—</td>
</tr>
<tr>
<td>Socioeconomic indicators</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Neighborhood income quintile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (lowest)</td>
<td>477 905 (19.56)</td>
<td>7290 (16.95)</td>
<td>470 625 (19.60)</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>463 963 (18.99)</td>
<td>7894 (18.37)</td>
<td>456 069 (19.00)</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>489 795 (20.04)</td>
<td>8837 (20.57)</td>
<td>480 858 (20.03)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>4</td>
<td>517 517 (21.18)</td>
<td>9270 (21.58)</td>
<td>508 247 (21.17)</td>
<td>—</td>
</tr>
<tr>
<td>5 (highest)</td>
<td>494 422 (20.23)</td>
<td>9680 (22.53)</td>
<td>484 742 (20.19)</td>
<td>—</td>
</tr>
<tr>
<td>ON-Marg deprivation quintile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (least)</td>
<td>687 806 (28.78)</td>
<td>11 994 (28.58)</td>
<td>675 812 (28.78)</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>538 836 (22.55)</td>
<td>9969 (23.76)</td>
<td>528 867 (22.53)</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>451 613 (18.90)</td>
<td>8242 (19.65)</td>
<td>443 571 (18.88)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>4</td>
<td>378 516 (15.76)</td>
<td>6597 (15.73)</td>
<td>369 919 (15.76)</td>
<td>—</td>
</tr>
<tr>
<td>5 (most)</td>
<td>334 940 (14.02)</td>
<td>5147 (12.27)</td>
<td>329 793 (14.05)</td>
<td>—</td>
</tr>
<tr>
<td>ON-Marg dependency quintile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (least)</td>
<td>725 830 (30.38)</td>
<td>11 163 (26.61)</td>
<td>714 676 (30.44)</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>528 201 (22.10)</td>
<td>9109 (21.71)</td>
<td>519 092 (22.11)</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>468 923 (19.54)</td>
<td>8721 (20.79)</td>
<td>458 202 (19.52)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>4</td>
<td>371 596 (15.55)</td>
<td>7160 (17.07)</td>
<td>364 430 (15.52)</td>
<td>—</td>
</tr>
<tr>
<td>5 (most)</td>
<td>267 167 (12.43)</td>
<td>5796 (13.92)</td>
<td>291 571 (12.41)</td>
<td>—</td>
</tr>
<tr>
<td>ON-Marg ethnic concentration quintile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (least)</td>
<td>271 450 (11.36)</td>
<td>5888 (13.99)</td>
<td>265 582 (11.31)</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>396 469 (16.59)</td>
<td>8430 (20.10)</td>
<td>388 039 (16.53)</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>416 902 (17.44)</td>
<td>8453 (20.15)</td>
<td>408 449 (17.40)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>4</td>
<td>517 598 (21.68)</td>
<td>9006 (21.47)</td>
<td>508 592 (21.66)</td>
<td>—</td>
</tr>
<tr>
<td>5 (most)</td>
<td>787 392 (32.95)</td>
<td>10 192 (24.30)</td>
<td>777 200 (33.10)</td>
<td>—</td>
</tr>
<tr>
<td>ON-Marg instability quintile</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 (least)</td>
<td>688 325 (28.80)</td>
<td>12 384 (29.52)</td>
<td>675 941 (28.79)</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>561 808 (23.51)</td>
<td>10 525 (25.09)</td>
<td>551 283 (23.48)</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>434 556 (18.18)</td>
<td>7748 (18.47)</td>
<td>426 808 (18.18)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>4</td>
<td>454 246 (19.01)</td>
<td>7461 (17.79)</td>
<td>446 785 (19.03)</td>
<td>—</td>
</tr>
<tr>
<td>5 (most)</td>
<td>250 876 (10.50)</td>
<td>5831 (13.13)</td>
<td>247 045 (10.52)</td>
<td>—</td>
</tr>
</tbody>
</table>

—, not significant.
distribution across age strata was similar and these estimates approximated Statistics Canada population estimates during the same time period. A total of 13.0% (n = 320 083) were identified as living in a rural region, and 7.6% (n = 186 568) were identified as having ≥1 previous fracture. When stratifying by the main predictor (baseline fracture versus no baseline fracture), there were significant differences in the age distribution, with over-representation of children ≥9 years of age and under-representation of those <9 years of age in the baseline fracture cohort. The baseline fracture cohort also had a significantly higher proportion of boys, children living in rural regions, and children with a history of previous fracture.

A total of 23.0% of children with a baseline fracture suffered ≥1 fracture during the 7-year follow-up period compared with 11.3% of children with no baseline fracture. This effect on the rate of subsequent fractures was observed early in the follow-up period and persisted throughout follow-up as evidenced by the divergent fracture-free survival curves in Fig 1 and was significantly different between these 2 groups (P < .001). There were differences in fracture-free survival between sexes, with 16.0% of girls and 26.9% of boys suffering ≥1 fracture during the 7-year follow-up period. The distribution of number of fractures during the follow-up period was also different between the baseline fracture groups, with a greater proportion of children in the baseline fracture group suffering 1 (18.3% vs 9.9%), 2 (3.8% vs 1.3%), and ≥3 fractures (0.9% vs 0.2%) than children with no baseline fracture during the follow-up period, respectively (Fig 2).

When adjusting for all available demographic, socioeconomic, and clinical covariates in a multivariable Poisson regression model stratified by age, the occurrence of a fracture at baseline was associated with an increased rate of subsequent fracture throughout childhood (Fig 3, Supplemental Table 3). Rate ratios in early childhood (0–5 years of age) were ~1.7 (range: 1.60–1.82) compared with later childhood
(6–15 years of age), which were \( \sim 1.50 \) (range: 1.48–1.56). A positive association with boys first became evident in children 6 years of age and increased over age strata to a peak at the age of 12 (rate ratio: 2.69; 95% confidence interval [CI]: 2.61–2.77) before declining slightly to age 15. The occurrence of soft-tissue injury had 1 of the strongest associations, with the subsequent fracture rate throughout childhood increasing gradually from age 0 (rate ratio: 1.96; 95% CI: 1.87–2.05) to age 5 (rate ratio: 2.38; 95% CI: 2.31–2.44), after which it remains constant at \( \sim 2.37 \) (range: 2.32–2.41). Exact rate ratio estimates and 95% CIs for all predictors can be found in Supplemental Table 3. Associations between fracture rate and both a history of previous fracture and the occurrence of head injury remained essentially static in the multivariable model across age strata, with rate ratios of \( \sim 1.5 \). A weak positive association between rural residence and subsequent fracture rate seen in the unadjusted analysis was no longer evident in the multivariable model.

**DISCUSSION**

Childhood fracture risk is a complex and dynamic issue with numerous biological, behavioral, and environmental factors proposed to affect a child’s fracture risk. Some of these factors, like an individual’s genes, which are believed to contribute an estimated 60% to 80% of the variability in an individual’s peak bone mass,\(^{28-30}\) are not modifiable. Other nonmodifiable factors known to affect fracture risk include \( \sim 2.4^{6,11,31} \) sex, \( \sim 2.4^{6,11,31} \) ethnicity,\(^{9} \) and seasonality.\(^{1,2,10,32}\) Some of the remaining 20% to 40%, however, may be modifiable and amenable to intervention to maximize peak bone mass, improve long-term bone health, and reduce fracture risk. Modifiable risk factors associated with an increased childhood fracture risk include obesity,\(^{33} \) poor nutrition,\(^{34-38} \) low bone mineral density,\(^{39-41} \) the built environment,\(^{42-45} \) and increased sports participation.\(^{3,4,46-48} \) Many of these risk factors influence numerous health outcomes beyond fractures and are sensible targets for both individual-level and population-level interventions.

In this study, having a baseline fracture remained a significant predictor of future fractures after adjustment for sex, rurality, history of previous fracture, and the occurrence of soft-tissue and head injuries. This effect was seen across all age strata, which suggests that the factors responsible for this phenomenon were present from an early age. By controlling for the occurrence of soft-tissue injury (the most common type of injury) and head injury (among the most severe type of injury), we were able to indirectly adjust for children who are more likely to sustain all types of injury. This is a heterogeneous group of individuals but encompasses a spectrum of children, from those who engage in risky activities as a result of behavioral factors to those who engage in athletic activities and are at risk as a result of environmental factors.

The remaining association between baseline fracture and future fractures has several possible explanations. The increased risk of second fracture after baseline fracture may indicate a child with (1) higher activity level, (2) risky behavior, (3) risky environment, or (4) weaker bones. Adjusting for other injuries should control to some extent for 1, 2, and 3; however, in this study design, the possibility of residual confounding cannot be ruled out.

Several other predictors remained strongly associated with childhood fracture, including sex and the occurrence of soft-tissue and head injuries. Male sex became a strong...
predictor of fracture only after age 5 and continued to increase to a peak at age 12. Children younger than 5 spend most of their time engaging in supervised play in lower-kinetic energy environments and are thus protected from unintentional injury.

The effects of baseline fracture and history of previous fracture were slightly stronger in the youngest age strata (0–5 years of age). This is consistent with studies from New Zealand, which found that age <4 years at first fracture conferred a higher risk of subsequent fracture compared with first fractures at older ages. Authors of the New Zealand study suggested younger age at first fracture was a marker of poor bone quality, perhaps related to poor nutrition. An alternative explanation is that repeated injuries in young children may be related to abuse. We excluded fractures with documented abuse from our study, but administrative ED data may not be able to identify all such instances.

Strengths and Weaknesses of the Study

The major strength of this study is the use of prospectively collected administrative data to generate population-level estimates of fracture incidence in a socially, ethnically, and geographically diverse region. This is, to our knowledge, the largest population-based study of childhood fracture epidemiology to date and the first population-based study of childhood fractures in North America. It is also the largest longitudinal assessment of childhood fracture patterns to date. The study population is similar demographically and with respect to the anatomic location and mechanism of injury presented in other publications, so the results of this study can likely be generalized to other populations that possess demographic and socioeconomic profiles similar to the province of Ontario. Unlike retrospective observational childhood fracture studies, fracture events in our databases were recorded prospectively, avoiding reliance on parental recall of childhood fracture, which has previously been found to be poor. Administrative databases that include ED visits have been shown to provide an unbiased estimate of fracture incidence because fractures require specialized care (radiographs, application of a splint, and referral to an orthopedic surgeon) that cannot be provided in other nonurgent settings. In addition, robust modeling strategies were used to analyze the rate of fractures in this population providing additional information about the secondary risk factors included in the model. The final model highlights risk factors that can be readily identified in the clinical setting (demographics, previous fracture history, and other nonfracture injury history) and applied to children of all ages, providing front-line clinicians with qualitative estimates of each child’s future fracture risk.

There are several potential limitations of this study. First, data for the entire duration of childhood were not available from these databases, preventing the construction of a complete birth cohort. Second, administrative databases are limited in the breadth of clinical information they collect. Finally, some elements of the database have not been specifically validated (ie, external cause of injury code and OHIP fracture codes), and others have not been specifically validated in the pediatric fracture population.

These findings cannot definitively conclude that children who fracture repeatedly have poor bone quality because a direct measure of bone quality could not be obtained from our administrative databases. We were, however, able to demonstrate a population-level estimate of fracture risk associated with a baseline fracture when controlling for common factors known to contribute to childhood fracture risk. In this study, we present compelling evidence that fractures are not random events of childhood and provide useful information for clinicians and researchers to increase awareness of fracture risk in childhood.

Implications and Future Research

The occurrence of a fracture in childhood increases the rate of future fractures during the following 7 years. This increased risk is in addition to the increased risk associated with male sex, older age, history of previous fractures, and the occurrence of soft-tissue and head injuries. Children who present to a fracture clinic with multiple risk factors could be educated about their increased risk of future fractures and questioned regarding factors related to their bone health. It is important to note that there are several safe, cost-effective, and easy-to-administer interventions available to improve bone quality in children if a child is identified as having poor bone quality before the period of bone development is complete. They include calcium supplementation, increased protein and dairy intake, vitamin D supplementation, and increased weight-bearing physical activity. Many of these interventions are also potentially beneficial at the population level and may confer health benefits beyond reducing the risk of childhood fracture.

With this study, we provide a foundation for future research. Identifying the biological determinants of the observed increased fracture risk requires information not currently available in population-based data. Determining if identifying fracture-prone children can be used to identify modifiable bone health issues in themselves or among their older relatives may be of considerable importance given the increasing societal and health care burden of age-related osteoporosis.
CONCLUSIONS
Childhood fractures are common events and are not distributed randomly within the population. Observed future fracture rates vary considerably according to readily available clinical and demographic factors such as the child’s age, sex, previous fracture history, and history of other types of soft-tissue injuries. Identifying risk factors in children with fractures may be a useful strategy for secondary prevention of childhood fractures and may possibly have beneficial effects on long-term bone health in later adult life.

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ABBREVIATIONS
CI: confidence interval
ED: emergency department
ICD-10: International Classification of Diseases, 10th Revision
IRR: incidence rate ratio
OHIP: Ontario Health Insurance Plan
ON-Marg: Ontario Marginalization Index

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