Childhood Femur Fractures, Associated Injuries, and Sociodemographic Risk Factors: A Population-Based Study

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ABSTRACT. *Objective.* **The objectives of this study were to determine the incidence of femur fractures in Colorado children, to assess underlying causes, to determine the prevalence and predictors of associated injuries, and to identify potentially modifiable risk factors.**

Methods. **The study population included all Colorado residents who were aged 0 to 17 years at the time of injury between January 1, 1998, and December 31, 2001. Cases of femur fracture were ascertained using the population-based Colorado Trauma Registry and *International Classification of Diseases, Ninth Revision, Clinical Modification* codes 820.0 to 821.39. Associated injuries with an Abbreviated Injury Scale of 2 or higher were classified into 5 categories. Poisson regression, small area analysis, and multivariate logistic regression were used to identify predictors of femur fractures and associated injuries, respectively.**

Results. **During the study period, 1139 Colorado children (795 boys, 344 girls) sustained femur fractures, resulting in the incidence of 26.0 per 100 000 person-years. Rates were higher in boys than in girls in all age groups (overall risk ratio: 2.19; 95% confidence interval: 1.92–2.47) but did not differ by race/ethnicity. Femur fractures that were caused by nonaccidental trauma showed more distal and combined shaft + distal pattern; their incidence did not differ by gender or race but was higher in census tracts with more single mothers and less crowded households. Associated injuries were present in 28.6% of the cases, more often in older children. Fatalities occurred only among children with associated injuries. Children who were involved in nonaccidental trauma, motor vehicle crashes, or auto-pedestrian accidents were 16 to 20 times more likely to have associated injuries than those with femur fractures as a result of a fall. In small-area analysis, the incidence of femur fractures in infants and toddlers was higher in census tracts characterized by higher proportion of Hispanics, single mothers, and more crowded households. Among children 4 to 12 years of age, the incidence was higher in census tracts with fewer single-family houses and more crowded households. Finally, the incidence of femur fractures among teenagers was higher in rural tracts and those with a higher proportion of Hispanics.**

Conclusions. **Femur fractures and associated injuries remain a major cause of morbidity in children. Predictors of femur fractures change with age; however, the risk is generally higher among children who live in the areas with lower socioeconomic indicators. *Pediatrics* 2005; 115:e543–e552. URL: www.pediatrics.org/cgi/doi/10.1542/peds.2004-1064; *children, fractures, injury patterns, injury prevention and control.***

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ABBREVIATIONS. LOS, length of stay; ISS, Injury Severity Score; ED, emergency department; ICD-9-CM, *International Classification of Diseases, Ninth Revision, Clinical Modification*; E-code, external-cause code; SES, socioeconomic status; IQR, interquartile range; CI, confidence interval; NAT, nonaccidental trauma; RR, risk ratio; MVC, motor vehicle crash.

Injuries are one of the leading causes of death, morbidity, and disability among children around the world.[1] Each year, 1 in 5 children who live in the United States will be treated for injuries that are a major cause of medical costs for children ages 5 to 21 years and that account for ~20% of hospital admissions.[2]

Fracture is an outcome of 10% to 27% of all childhood injuries, contributing significantly to the mortality, morbidity, and costs of care.[3–6] There is an increasing secular trend in the incidence of fractures among children.[7] The cause of this increase is still unclear; however, an increase in sports-related fractures has been observed[8] and may be primarily responsible for the trends. It is also possible that better surveillance data contribute to the trend.

Femur fractures represent ~0.9% to 2.3% of all bony injuries in children.[9–11] In studies from Europe, the annual incidence of femur fractures has been previously reported to be 28.0 to 43.5 per 100 000 children.[9,11–13] To date, there is only 1 report of the incidence of femur fractures among children in the United States; a study from Baltimore reported a rate of 19.2 femoral shaft fractures per 100 000 children during 1990–1996.[14]

Significant skeletal trauma leading to femur fractures can also result in additional, extensive, and life-threatening injuries. "Waddell's triad," which consists of femur fracture, intra-abdominal or intrathoracic injury, and head injury, is recognized in clinical practice as associated with high-velocity accidents such as motor vehicle, auto-pedestrian, or bicycle crashes[15] but has not been previously studied epidemiologically in children. Knowledge of the mechanism of injury together with the child's age may lead to identification of specific patterns of injury. Awareness of these patterns could help emergency physicians to actively look for those injuries in patients and, by prompt and accurate diagnosis of additional injuries, to improve outcomes and decrease medical costs.[16]

The goals of this study were (1) to calculate age-, gender-, and race/ethnicity-specific incidence rates of femur fractures; (2) to assess mechanisms of injury that lead to femur fractures; (3) to determine the prevalence of associated injuries among children with femur fractures and the mechanism of injury that leads to specific injury patterns; (4) to explore the relationship between the presence of associated injuries in patients with femur fractures and factors such as survivorship, hospital length of stay (LOS), and Injury Severity Score (ISS); and (5) in a small-area analysis at the census tract level, to identify potentially modifiable risk factors or subpopulations at highest risk for femur fractures. Socioeconomic factors (eg, income, crowding, marital status) have been shown to affect the rates of injuries.[17,18] Although socioeconomic data were not available in our data set at the individual level, we used census-based socioeconomic characteristics of residential areas instead, an approach previously shown to approximate individual-level socioeconomic measures in health outcomes studies.[19]

METHODS

Study Design

This study involved 2 parts: (1) descriptive analyses of incidence rates by demographic groups, the mechanisms of injury resulting in femur fractures, and the prevalence and types of associated injuries in Colorado children aged 0 to 17 and (2) small-area analyses of socioeconomic status data using census tracts of residence aimed at detecting modifiable risk factors or populations at risk for femur fractures and associated injuries.

Study Population

The study population included all Colorado residents who were aged 0 to 17 at the time of injury and sustained a femur fracture between January 1, 1998, and December 31, 2001, whether they were hospitalized, were solely evaluated in an emergency department (ED), or died.

Case Selection

Cases were selected from the Colorado Trauma Registry, a population-based statewide database that includes information on hospitalizations and deaths as a result of injury in Colorado, by linking data from 3 sources: (1) death certificates obtained from the Vital Records Section at the Colorado Department of Public Health and Environment; (2) hospital discharge data from the Colorado Health and Hospitals Association, which includes data on all acute-care hospitalizations in Colorado; and (3) case abstract information collected by trauma nurse coordinators at all level I, II, and III trauma centers (25 of 63 acute-care hospitals in Colorado). Data were available from only 1 source for 32% of the cases (18% hospital discharge data and 14% case abstracts), from 2 sources for 67% of the cases, and from all 3 sources for 1% of the cases.

Definition of Injury

The *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) codes 820.0 to 821.39 were used to identify femur fractures. Femur fractures were categorized according to the ICD-9-CM classification system into 3 groups: proximal, shaft, and distal femur fractures.

A total of 1387 records that contained the ICD-9-CM codes for femur fractures were identified among children who were aged 0 to 17 in the Colorado Trauma Registry. Seventeen percent (N = 248) of the records were excluded from the analysis as a result of (1) non-Colorado residency (N = 148); (2) multiple admissions for the same fracture (N = 94); and (3) other reasons (N = 6) such as diagnoses coded as 733.1 (pathologic fracture), 733.81 (malunion), 733.82 (nonunion), 958 (early complications), and 905 to 909 (late complications). Therefore, this analysis included 1139 unique cases of femur fractures that met the inclusion criteria.

Associated Injuries

Associated injuries with an Abbreviated Injury Scale of 2 or higher[20] were classified into 5 general categories: head and neck (ICD-9-CM codes 800–801, 804–806, 850–854, 900, 925, 950, and 951), face (ICD-9-CM codes 802, and 870–873), chest (ICD-9-CM codes 806.2–806.3, 860–862, and 901), abdomen and pelvis (ICD-9-CM codes 806.4–806.8, 863–868, 878, and 902), and additional injuries involving extremities (ICD-9-CM codes 810–819, 820–829, 887, 895–897, 903, 927–929, and 956–957). The Abbreviated Injury Scale was assigned manually by the trauma nurses (82%) or by commercially available software (18%).

Mechanism of Injury

External-cause (E-code) data and a description of the injury were reviewed for each patient to determine the mechanism of injury and place of occurrence.

Demographic and Socioeconomic Data

Age, gender, race/ethnicity, and address of residence were obtained from primary data sources. When there was discrepancy between data sources, the data from the case abstract were used. For calculating rates, annual intercensal estimates of Colorado population were obtained from the Colorado State Demographer on the basis of the 1990 and 2000 US Census data for the denominator rates.

In the small-area analyses, census tract, rather than case of femur fracture, was the unit of analysis.[21] The 2000 US Census data were used to assign socioeconomic indicators such as urban/rural status, family income, childhood poverty, single parenthood, crowding, and education achievement to each of the 1062 Colorado census tracts. Descriptive characteristics of the census tract–level socioeconomic status (SES) variables are summarized in Table 1.[22]

Statistical Analysis

Descriptive Analyses

Medians and interquartile ranges (IQRs) were calculated for demographic characteristics. Crude and strata-specific annual incidence rates were calculated per 100 000 with the 95% confidence interval (CI) based on the Poisson distribution.[23] The prevalence of additional injuries was calculated per 100 people with femur fracture with 95% CI based on the binomial distribution.

Multivariable Analysis

Backward stepwise logistic regression analysis was used to identify risk factors for femur fractures and associated injuries. The Hosmer-Lemeshow method was used to assess model goodness of fit.[24] All analyses were performed using SAS software version 8.2 (SAS Institute, Inc, Cary, NC).

Small-Area Analyses

Cases of femur fracture were geocoded into their respective census tracts defined by the 2000 census using the location of residence. Of the 1139 cases of femur fracture, 34 were excluded from small-area analyses because of lack of residence address or insufficient population in the tracts, leaving 1015 (97.0%) of the cases available for the analyses. Poisson regression models were fitted using the SAS GENMOD procedure. The population of each of the 1105 tracts with childhood population >50 was further divided into 6 age- and gender-specific strata to allow adjustment for age and gender. Each of the 1105 cases was assigned to the specific gender-age stratum within a census tract. In all models, the highest SES group was selected as the reference category. The models showed reasonable fit as determined by the likelihood

TABLE 1. Range of Values for Census Tract Socioeconomic Indicators Among the 1015 Colorado Census Tracts Used in the Analysis

Socioeconomic Indicator	Range of Values Across Census Tracts	Median	IQR	Categorization/ Transformation*
Live in urbanized area, %	0.0–100.0	100	13.0	Ln(1 + value)
Family income, census median	$7852–$200 001	$52 972	$29 416	Quartiles
Child poverty, %†	0.0–78.5	8.5	13.5	Ln(1 + value)
College attainment, %‡	0.0–46.8	19.6	18.0	Continuous
Single motherhood, %	0.0–90.2	15.1	14.4	Quartiles
Race/ethnicity, %				
Hispanic children	0.0–92.3	15.0	23.1	Quartiles
White children	10.0–100.0	83.8	21.1	Quartiles
Single-family housing, %	0.0–100.0	75.1	28.6	Quartiles
Household crowding, %§	68.7–100.0	97.1	4.5	Quartiles

* Categorization into quartiles or the ln(1 + value) transformation was used before analyses unless the data were normally distributed.
† Percentage of the population <18 years old living below poverty level.
‡ Percentage of the population >25 years old with a college degree.
§ Percentage of the households with ≤1 person per room.

ratio statistic or deviance.[25] The 95% CIs were adjusted for overdispersion.[25] Additional Poisson regression models were fitted to assess the SES factors that predict femur fractures as a result of nonaccidental trauma (NAT) among children 0 to 3 years of age.

Human Subjects

The Colorado Multiple Institutional Review Board reviewed and approved this study.

RESULTS

From 1998 to 2001, 1139 children and youth had femur fractures in Colorado, 795 (69.7.0%) of whom were boys and 344 (30.3%) were girls. There were 25 fatalities, resulting in a case fatality rate of 2.3%. The children died from associated injuries: 15 from head injury, 6 from multiple injuries, 3 from thorax injury, and 1 from abdominal trauma.

The median age of children with femur fractures was 8 years, with an IQR from 3 to 14. There were 754 non-Hispanic whites (66.2%), 236 Hispanics (20.7%), 49 blacks (4.3%), and 100 children of other or unknown race/ethnicity (8.8%).

The most frequent location of the fracture was the femoral shaft (62.5%) followed by the proximal (12.5%) and distal (11.7%) femur. Nearly 1 in 8 (13.3%) fractures involved the femoral shaft fracture in combination with a proximal or distal fracture.

Incidence

The annual incidence rate of all types of femur fractures was 26.0 per 100 000 (95% CI: 24.4–27.7). For all age groups, boys had higher rates than girls (risk ratio [RR]: 2.19; 95% CI: 1.92–2.47; Table 2 and Fig 1). The incidence of all femur fractures showed peaks in infants (girls) and toddlers (boys) as well as in older teenagers (both genders). The incidence of femur fractures was similar across race/ethnic groups, although it was slightly lower among Hispanics. Similar patterns were seen for femoral shaft fracture (Table 2). Fractures were 25% more common during late winter and late summer/early fall. There was also a correlation between the time of day, with the fracture frequency peaking between 4 and 6 PM (data not shown).

Mechanism

The mechanism of injury resulting in femur fractures differed by age group (Table 3). Among children younger than 3 years, the most common cause of femur fracture was fall. The second most common cause was NAT. Fall was also the most common cause of femur fracture among young school-aged children (39.0%) followed by motor vehicle crash (MVC; 13.5%), pedestrian (13.3%), and bicyclist (12.4%) injuries. The most common cause of femur fracture among adolescents was MVC (43.3%). Sport-related activity led to 202 (17.7%) femur fractures, and 41 (20.3%) of those resulted from skiing/snowboarding.

TABLE 2. Incidence of Femur Fractures Among Children 0 to 17 Years Old: Colorado, 1998–2001

Category	All Types of Fractures			Shaft Fractures		
	N	Rate*	95% CI	*N*	Rate*	95% CI
Total	1139	26.0	24.4–27.7	860	19.6	18.3–21.0
Female	344	16.1	14.5–17.9	245	11.5	10.1–13.1
Male	795	35.4	33.0–37.9	615	27.4	25.3–29.5
Race/ethnicity†						
Non-Hispanic white	754	25.9	24.1–27.9	574	19.7	18.1–21.4
Hispanic	236	22.8	19.9–25.7	183	18.0	15.5–20.9
Black	49	26.0	19.1–34.2	34	17.7	12.3–24.7
Age group, y						
0–3	332	34.6	30.0–38.6	282	29.4	26.1–33.1
4–12	451	20.5	18.7–22.5	343	15.6	14.0–17.4
13–17	356	29.3	26.3–32.6	235	19.3	16.9–22.0

* Per 100 000 person-years.
† Other/unknown race/ethnicity, $N = 97$ (all types of fractures)/$N = 69$ (shaft fractures).

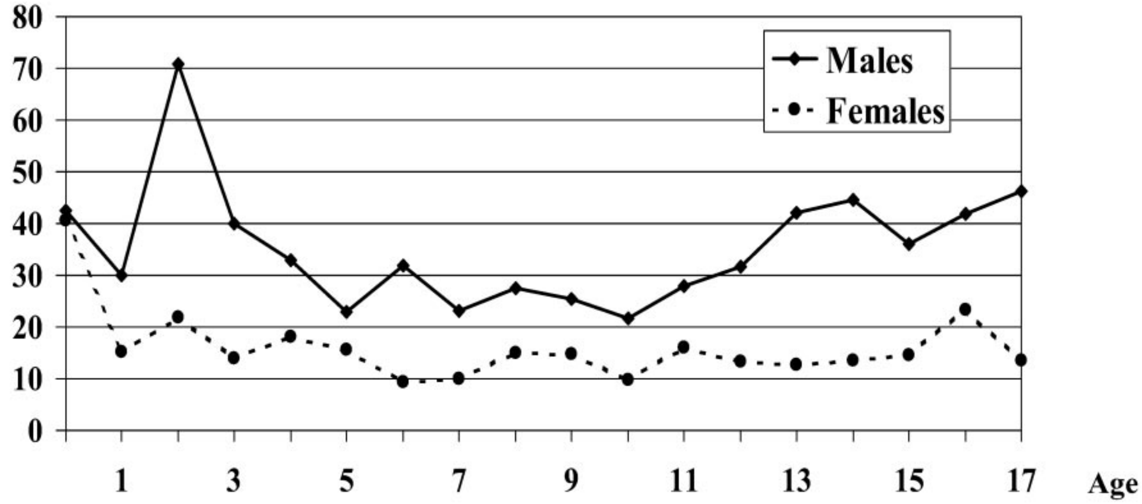

Fig 1. Incidence rates of femur fractures per 100 000 person-years: Colorado, 1998–2001.

TABLE 3. Mechanisms of Injury Resulting in Femur Fractures: Colorado, 1998–2001

Causes of Injury	Age, y					
	0–3 (*N* = 332)		4–12 (*N* = 451)		13–17 (*N* = 356)	
	n	%	*n*	%	*n*	%
All unintentional	283	85.2	448	99.4	347	97.5
MVC*	20	6	61	13.5	154	43.3
Bicyclist	4	1.2	56	12.4	17	4.8
Pedestrian	10	3.0	60	13.3	24	6.7
Falls	214	64.5	176	39.0	80	22.5
Struck by person/object	24	7.2	55	12.2	44	12.3
Other	11	3.3	40	8.9	28	7.9
All intentional	49	14.8	3	0.6	9	2.5
NAT	48	14.5	1	0.2	0	0.0
Other intentional	1	0.3	2	0.4	9	2.5

* Includes motor vehicle occupants and drivers.

TABLE 4. Characteristics of Children Aged 0 to 3 Years With Femur Fractures Caused by NAT Versus Other Mechanisms: Colorado, 1998–2001

Patient Characteristics	Mechanism	
	NAT (*N* = 48)	Other (*N* = 278)
Median age, y*	0	2
Gender, %		
Male	62.5	68.4
Female	37.4	31.6
Race, %		
Non-Hispanic white	54.2	55.8
Hispanic	6.2	3.6
Black	31.3	29.1
Other/unknown	8.3	11.5
Location of injury, %		
Home	80.0	67.3
Other/unknown	17.9	9.7
Public	2.1	7.5
Recreation	0.0	4.0
Street	0.0	10.8
Type of femur fracture, %		
Shaft	58.3	77.3
Distal	18.7	5.4
Shaft + distal	16.7	4.7
Shaft + proximal	6.3	4.0
Proximal	0.0	8.6

* $P = .0001$.

Femur Fractures Among the Youngest Children

NAT was defined as E-codes 967.0 to 967.9. Among children younger than 4 years, 48 (15%) of femur fractures cases were caused by NAT. Table 4 summarizes characteristics of the cases of femur fractures caused by NAT versus other mechanisms. Children with femur fractures caused by NAT were younger, even within this narrow age range, but there was no significant difference in gender or race. Relatively more NAT-related injuries than others happened at home or at an undisclosed location. Shaft fractures were relatively less common, whereas distal fractures and combined shaft + distal fractures were more common, in cases of NAT-related injuries, compared with those as a result of other causes.

Associated Injuries

A total of 326 of the 1139 children with femur fracture had associated injuries recorded, which resulted in a prevalence of 28.6% (95% CI: 26.0%–31.3%). Of the children with associated injuries, 216 were boys and 110 were girls. Girls had a higher prevalence of associated injury than boys: 32.0% vs 27.2% (prevalence ratio: 1.18; 95% CI: 1.16–1.20). The median age of children with femur fractures and associated injuries was 12 years (IQR: 6–16). In both genders, the prevalence of associated injuries was highest in the late teenage years.

Table 5 summarizes univariate comparisons of the characteristics of children with femur fractures with and without associated injuries. Children with associated injuries were significantly older than children with isolated femur fractures. The injury mechanisms that led to femur fractures with associated injuries differed significantly from those with isolated femur fractures. Falls or being struck led to associated injuries in only 6.2% and 7.3% of cases, respectively. In contrast, associated injuries were present in nearly 70% of children with femur fractures as a result of MVC and 55% of children with femur fractures as a result of NAT or auto-pedestrian accidents. As expected, the ISS and hospital LOSs

TABLE 5. Characteristics of Children With Femur Fractures, With and Without Associated Injury: Colorado, 1998–2001

Patient Characteristics	No Associated Injury (N = 813)	Associated Injury (N = 326)	P Value
Median age, y	7	12	.0001
Gender, %			.0994
Male	71.2	66.3	
Female	28.8	33.7	
Race, %			.0016
Non-Hispanic white	64.5	70.6	
Hispanic	21.3	19.3	
Black	4.1	4.9	
Other/unknown	10.1	5.2	
Mechanism of injury, %			<.0001
MVC	7.6	36.5	
NAT	1.9	3.1	
Fall	59.4	24.0	
Pedestrian	3.3	14.6	
Bicyclist	5.6	11.5	
Struck by person/object	14.5	4.2	
Median ISS, d (range)	9.0 (4.0–19.0)	17.0 (4.0–75.0)	<.0001
Median LOS, d (range)	2.0 (0.0–38.0)	4.0 (0.0–59.0)	<.0001
Case fatality, n (%)	0 (0.0)	25 (8.0)	<.0001

were also significantly higher in children with associated injuries. The case fatality rate among children with associated injuries was 8.0% compared with 0% among children without associated injuries. The racial/ethnic distribution among those with associated injuries compared with those without associated injuries was statistically different. There was higher proportion of non-Hispanic white children and those of other/unknown race and lower proportion of Hispanic children.

Associated injuries were most often additional injury to 1 or more extremities (30.9% of all associated injuries), the head and neck (9.5%), and the face (8.6%). A combination of femur fracture and additional injury to the same extremity or to another extremity and to the head and neck was present in 20 children, or 6.1% of those with associated injuries. Combinations of associated injuries to 3 to 5 regions were frequent, present in 28.2% of children with associated injuries. "Waddell's triad," which consists of femur fracture, intra-abdominal or intrathoracic injury, and head injury, was present in 83 (25.5%) children with associated injuries. In addition, 3.4% had an injury to face, chest and/or abdomen/pelvis, and femur fracture. In all age groups, an additional extremity injury followed by head and neck injury was most frequent, and the prevalence of those increased with child age. Teenagers had the highest prevalence of associated injuries, ranging from 16% with chest injury to 29% with an additional extremity injury. The prevalence of chest injury compared with other injuries was relatively high among very young children as a result of NAT (Fig 2).

The distribution of injury mechanisms that resulted in associated injuries to various body regions is summarized in Fig 3. The likelihood of injuries to the head/neck region was highest in cases as a result of NAT and MVC or pedestrian or bicycle accidents. Injuries to the chest, abdomen, and pelvis were most likely in cases of NAT and MVC or pedestrian accidents.

Logistic regression analysis was used to identify independent predictors of associated injury among children with femur fracture (Table 6). Older age was associated with an almost three-fold higher risk for associated injury than children aged 2 to 5. Hispanic ethnicity was associated with ~36% lower risk. Children who were subjected to NAT or involved in MVC or auto-pedestrian accidents were 16 to 20 times more likely to have associated injuries than children with femur fractures caused by falls.

Small-Area Analysis of Socioeconomic Indicators That Predict Childhood Femur Fractures

Several tract-level socioeconomic (SES) indicators were evaluated for analysis, including median family income, the proportion of children living in poverty, the proportion of single mothers, the proportion of Hispanics, the proportion of adults with college education, and tract urbanization. In univariate analyses, all indicators were associated with femur fractures; however, several showed high correlations with each other (data not shown). Because of this, selecting a multivariate model could be somewhat arbitrary. Therefore, multivariate models were built by adding a new variable only when comparison of the deviance of nested models with and without the variable indicated significant improvement in fit. Because there were interactions between age (especially teen years 13–17) and several other variables, age-stratified Poisson regression models were fit. Results are summarized in Table 7.

As expected, male gender was a strong predictor of femur fracture in all 3 age groups. Adjusting for gender and family income, the incidence of femur fractures in infants and toddlers was higher in census tracts characterized by higher proportion of Hispanics, single mothers, and more crowded households. In this age group, higher income seemed to be a risk factor for femur fractures. Among children 4 to 12 years of age, the gender-adjusted incidence was higher in census tracts with fewer single-family houses and more crowded households. Finally, the gender-adjusted incidence of femur fractures among

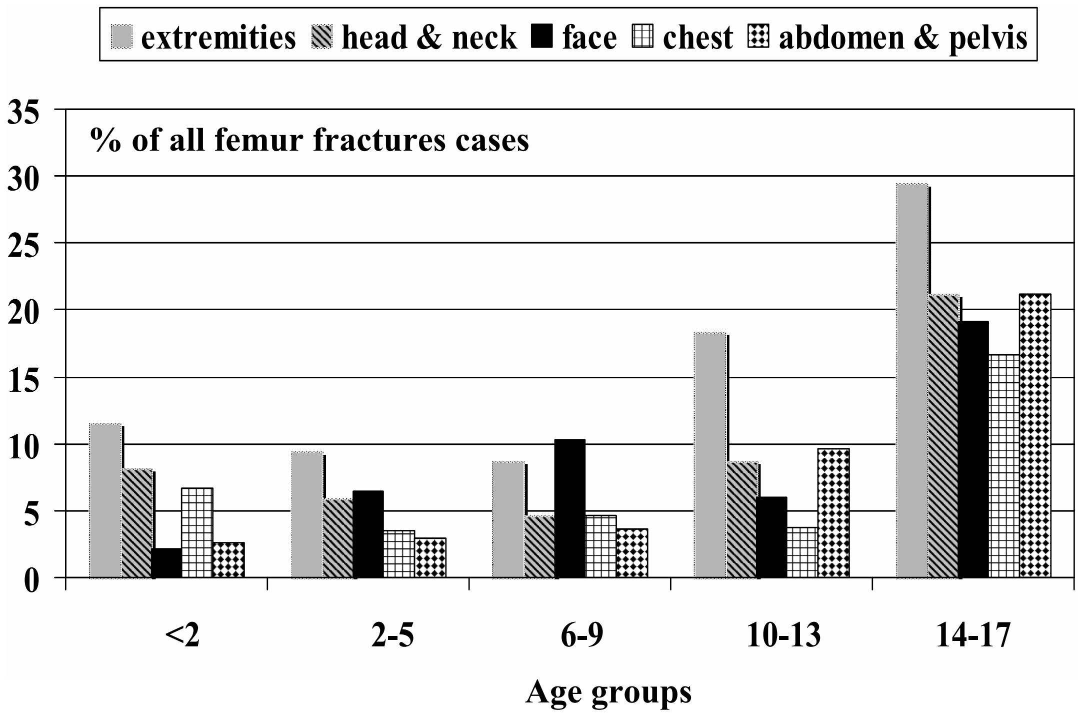

Fig 2. Body region of associated injuries in children with femur fractures according to age.

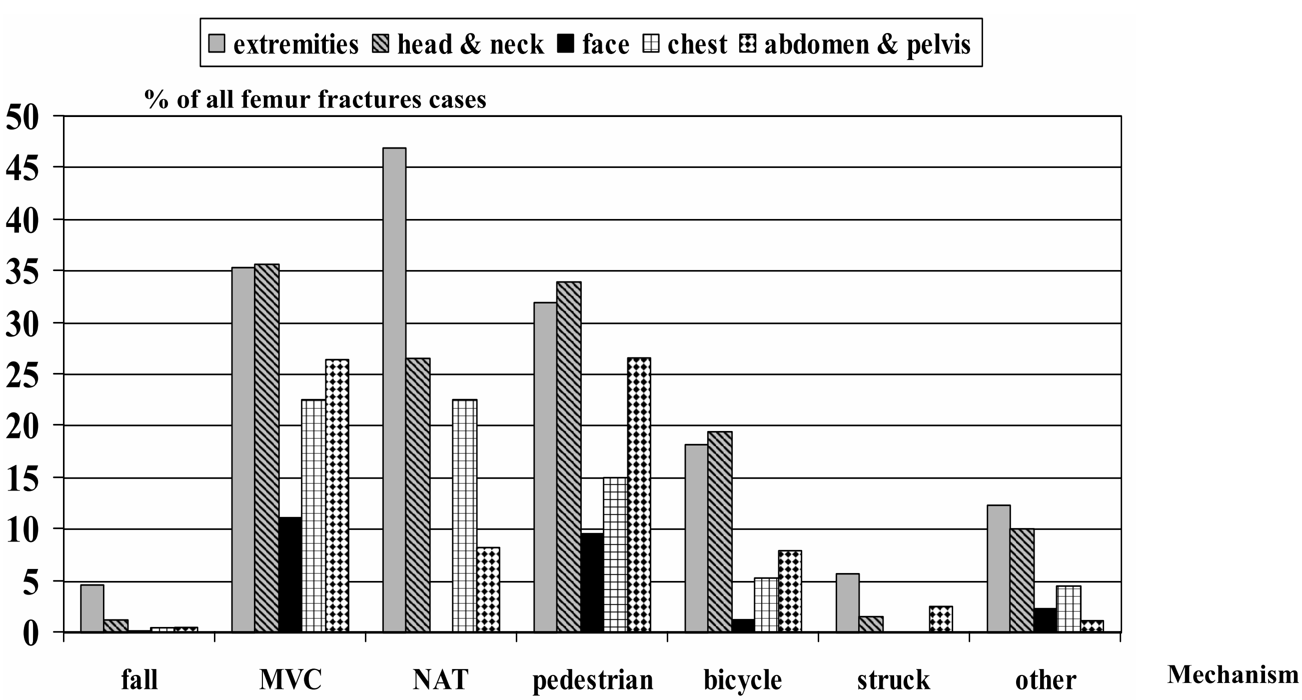

Fig 3. Body region of associated injuries in children with femur fractures according to mechanism.

teenagers was higher in rural tracts and those with a higher proportion of Hispanics. Because ecological socioeconomic indicators should be considered in combination rather than assigned specific individual meaning, on balance, these results suggest that lower SES is a risk factor for femur fractures except for the group of very young children. In small-area analysis, the incidence of femur fracture caused by NAT among children younger than 4 was higher in census tracts with a higher percentage of single mothers (RR: 1.21; 95% CI: 1.09–1.33) and in tracts with less crowded households (RR: 1.64; 95% CI: 1.12–2.38).

DISCUSSION

These results demonstrate that the incidence of childhood femur fractures in Colorado (26/100 000) is ~10% to 70% lower than in most European studies (28–45/100 000).[9,13,26] To allow for a direct comparison, we separately calculated the incidence of fem-

TABLE 6. Predictors of Associated Injuries Among Children With Femur Fractures

Predictor	OR*	95% CI*	*P* Value*
Gender (female vs male)	1.30	0.89–1.81	.19
Race			
Non-Hispanic white	1.00		
Hispanic	0.64	0.43–0.97	.034
Black	1.20	0.58–2.55	.61
Other	1.50	0.53–4.21	.44
Unknown	0.22	0.09–0.58	.019
Age, y			
<2	1.31	0.68–2.54	.42
2–5	1.00		
6–9	1.20	0.64–2.24	.58
10–13	1.98	1.10–3.60	.024
14–17	2.90	1.64–5.09	.0002
Mechanism			
Falls	1.00		
NAT	20.3	9.7–42.7	<.0001
Auto-pedestrian	16.70	9.4–29.7	<.0001
MVC	18.80	11.8–30.1	<.0001
Bicycling accident	7.30	3.9–13.5	<.0001
Other	1.20	0.64–2.3	.55

* Multivariate logistic regression with all variables simultaneously in the model.

oral shaft fractures, which was very similar to that reported from Baltimore, MD, for 1990–1996.[14]

Similar to other studies,[9,14] we found that boys have a higher incidence of femur fractures compared with girls. The majority of sports-related injuries were in boys, which is consistent with previous findings showing that sports participation tends to increase fracture risk in boys and decrease the risk in girls.[27] In contrast to the Baltimore study, which reported a higher incidence of femur fractures in black children than non-Hispanic whites,[14] our data showed little difference in incidence by ethnicity. Higher rates among blacks in Baltimore were primarily attributable to auto-pedestrian and firearm injuries (15%). Those mechanisms were less frequently seen in Colorado.

Consistent with previous studies of femur[10,12,14,26] and other types of fractures,[15] we found a bimodal age distribution with the first peak in early childhood and the second in midadolescence. This bimodal distribution is probably an effect of the progressive increase in bone strength during bone development. In early childhood, the femur is relatively weak and breaks under load conditions reached in falls from lower heights. In adolescence, high-velocity trauma is required to reach the stress necessary for fracture.[15]

As expected, the mechanism of femur fractures changed with the age of the child. In children who were too young to walk, most of the fractures resulted from NAT, consistent with previous observations.[10,28–30] In contrast, isolated femoral shaft fractures in older children are rarely attributable to intentional injury,[31,32] and in our study, falls were the main cause in children who were younger than 12 and MVCs were the main cause in teenagers. These findings are similar to those previously reported.[10,14,33] In the Colorado population, at least 18% of children had femur fractures related to sports, with 22% of those caused by skiing or snowboarding.

Previous studies reported a slight increase in the incidence of femur fractures in the summer, with peak in May and August and low rates in July and December.[34,35] In contrast, femur fractures in Colorado were more common during late winter months and late summer/early fall months. This reflects femur fractures related to sports activities such skiing and snowboarding in winter and football during late summer and fall.

There is a correlation between the time of day and frequency of femur fractures. The majority of fractures happened between 4 and 6 PM, at the time of day when children are most active.

The prevalence of associated injuries among children with femur fractures in our population-based study (28%) was within the range of 20% to 40% reported from previous case series.[13,26,33,36] In all age groups in the Colorado population, the typical pattern included an additional injury to extremity, head and neck, or chest (especially with MVC or NAT). It is important to recognize this pattern because the presence of head or thoracic injury has been shown to be associated with higher mortality.[37,38] We found "Waddell's triad" in 25.5% of all cases of femur fracture with associated injuries. The typical mechanisms that led to associated injuries that emerged from our work were high-impact accidents such as MVC involving teenagers, auto-pedestrian accident in children of any age, and NAT in infants and toddlers. In patients who were injured by high-impact mechanism, we strongly recommend careful evaluation of head, neck, chest, and abdomen that may lead to prompt detection of severe associated injuries and improve the patient's outcome.

The ISS was significantly higher and the hospital LOS was significantly longer for children with associated injuries. Previous studies have shown that the mean hospital LOS for femur fracture is almost 3 times that of all other patients seen in the emergency unit.[12,26] The resource utilization by children with femur fracture is very high compared with other childhood fractures.[39]

Previous studies have shown higher rates of injuries,[40] including fractures,[14,41] in children from lower socioeconomic strata than in those from higher strata. Larger family size and the presence of older children increase the risk for injuries that require hospitalization[42]; lower maternal age and single motherhood significantly increase the rate of both unintentional and intentional infant injury mortality.[43] Non-Hispanic white children and children from affluent families have been shown, conversely, to be at increased risk for recreational injury.[44] The results of our study confirm that lower SES increases the risk for femur fractures in children. Colorado infants and toddlers who lived in areas with a higher proportion of Hispanic population and crowded households headed by single mothers were at a particularly high risk and may benefit from childhood injury prevention strategies. An unexpected finding was higher risk for femur fracture among children who were aged 0 to 3 and living in higher income families. Detailed case-specific data were not available, but children from census tracts with highest median in-

TABLE 7. Age-Stratified Multivariate Poisson Regression Models Exploring the Relationship Between Census Tract–Level Socioeconomic Indicators and Femur Fractures

Age, y	"Best" Model	RR (95% CI)	*P* Value
0–3	Gender (male vs female)	2.10 (1.63–2.64)	<.0001
	Family income, quartiles		
	<$40 912	0.65 (0.39–1.07)	.090
	$40 912–$52 971	0.57 (0.36–0.89)	.015
	$52 972–$70 328	0.56 (0.37–0.85)	.006
	>$70 328	1.00	
	Race/ethnicity of children in the tract		
	>31% Hispanic	2.91 (1.67–5.10)	.0002
	15–31% Hispanic	2.07 (1.26–3.44)	.004
	7.7–14.9% Hispanic	1.62 (1.05–2.51)	.030
	<7.7% Hispanic	1.00	
	Single motherhood (per 10% increase)	1.14 (1.01–1.28)	.039
	Household crowding		
	<94.1% noncrowded households*	1.02 (0.62–1.69)	.919
	94.1–97.0% noncrowded households	1.62 (1.03–2.52)	.034
	97.1–98.6% noncrowded households	1.43 (0.94–2.18)	.093
	>98.6% noncrowded households	1.00	
4–12	Gender (male vs female)	2.00 (1.61–2.48)	<.0001
	Single-family housing		
	<60.1%	1.37 (0.97–1.94)	.072
	60.1–75.0%	1.28 (0.92–1.79)	.15
	75.1–88.7%	1.47 (1.07–2.00)	.016
	>88.7%	1.00	
	Household crowding		
	<94.1% noncrowded households	1.70 (1.2–2.42)	.003
	94.1–97.0% noncrowded households	1.54 (1.08–2.18)	.015
	97.1–98.6% noncrowded households	1.53 (1.09–2.15)	.017
	>98.6% noncrowded households	1.00	
13–17	Gender (male vs female)	2.77 (2.18–3.52)	<.0001
	Rural residence	1.15 (1.09–1.22)	<.0001
	Race/ethnicity of children in the tract		
	>31% Hispanic	1.39 (1.03–1.86)	.030
	15–31% Hispanic	1.14 (.85–1.54)	.380
	7.7–14.9% Hispanic	1.01 (0.75–1.36)	.960
	<7.7% Hispanic	1.00	

All variables simultaneously in the most-parsimonious model for each age group.
* Percentage of households with <1 person per room.

come had 2.5 to 5.0 times more injuries happening in a recreational setting and related to outdoor activities that may be responsible for higher overall risk for femur fractures among those young children.[44]

The observed increased risk for femur fractures among children who live in rural areas is consistent with motor vehicle injury data.[45] The use of protective gear is lower in rural populations.[46] Hispanic drivers in Colorado have been shown to have lower rates of safety belt use and higher rates of speeding, invalid licensure, and alcohol use, leading to higher rates of death in traffic crashes.[47] Traveling in pickup trucks and all-terrain vehicle use by children and adolescents, often with inadequate protective gear and careless riding habits, are frequent in rural areas.[48,49] Another significant risk factors for injuries among rural youths is use of alcohol.[50] Adolescents and children, also those who live in rural areas, would benefit from school- or community-based interventions to improve motor vehicle–related safety, particularly interventions to reduce alcohol-impaired driving.[51]

Young children who present with femur fractures require careful evaluation for possibility of a NAT. Spiral or oblique femur fractures have been shown to be highly related to NAT.[30,31] Our finding of increased prevalence of distal and combined (shaft + distal) fractures among abused patients suggests a need for more detailed evaluation of the injury mechanisms among patients with this type of femur fracture.

The finding of the higher risk for NAT-related fractures among children from census tracts with a higher percentage of single mothers and less crowded households is consistent with previous studies and carries important injury prevention implications.[52,53] Single mothers who are raising young children without a significant family support will likely benefit from enhanced anticipatory guidance for injury prevention, particularly prevention of NAT. All available support services such as nurse home visits and appropriate child care services should also be available for this population.

The majority of femur fractures among the youngest children happen at home secondary to falls. Anticipatory guidance regarding specific home-safety practices such as safety straps when a child is in the high chair or booster seat, safety gates on the stairs, not leaving the child on the changing table, and avoiding furniture that the child can climb should be addressed to prevent falls and femur fracture.[54] Pediatricians have a critical role in educating parents and children in the area of injury prevention and identifying families who are in need of additional support. Enhanced anticipatory guidance for injury prevention is one of the ways to increase parental and child understanding of safety practices.[55]

Interventions to reduce injury risk can be also done in other settings than the primary physician's office. Brief counseling in the EDs on behaviors and practices related to injury prevention leads to improved home safety, seatbelt, and bicycle helmet use.[56,57] School- and community-based programs that yield improvement in safety practices by parent safety education, home inspection, and the distribution of safety supplies seem to improve knowledge and behavior related to injury prevention and decrease the risk for injury.[58–60]

Our study, although population based and the largest to date in the United States, has several important limitations. The numerator data were obtained from a trauma registry, which contains only data on patients who had significant injuries and were seen in an ED or hospitalized. We believe that virtually all children with femur fractures are seen initially in these settings, but some cases could be missed. Very few cases were identified only from the death certificates, and among children who died as a result of multiple injuries, diagnosis of femur fracture might be missed. Another limitation is the lack of specific socioeconomic indicators for each of the cases, but characteristics can be estimated reasonably at the census-tract level.[19] The use of ICD-9-CM codes to identify patients could lead to misclassification bias, depending on the accuracy of medical records coding. However, ICD-9-CM codes and E-codes have been shown to be feasible and reliable for injury surveillance.[61]

CONCLUSIONS

We demonstrated a lower-than-expected incidence of femur fractures in Colorado children but a high prevalence of associated injuries. This study showed that patterns of associated injuries are related to the child's age and mechanism of injury. The results of this study provide the first description of detailed population-based predictors of femur fractures and associated injuries and identified populations at risk, suggesting directions and target populations for future interventions.

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Childhood Femur Fractures, Associated Injuries, and Sociodemographic Risk Factors: A Population-Based Study

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