ORIGINAL ARTICLE

The Association Between Fracture Rates and Neighborhood Characteristics in Washington, DC, Children

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Background: Effects of neighborhood contextual features have been found for many diseases, including bone fractures in adults. Our study objective was to evaluate the association between neighborhood characteristics and pediatric bone fracture rates. We hypothesized that neighborhood indices of deprivation would be associated with higher fracture rates.

Materials and Methods: Pediatric bone fracture cases treated at a tertiary, academic, urban pediatric emergency department between 2003 and 2006 were mapped to census block groups using geographical information systems software. Fracture rates were calculated as fractures per 1000 children in each census block. Exploratory factor analysis of socioeconomic indicators was performed using 2000 census block data. Factor scores were used to predict odds of bone fracture at the individual level while adjusting for mean age, sex composition, and race/ethnicity composition at census block level using our sample data.

Results: We analyzed 3764 fracture visits in 3557 patients representing 349 distinct census blocks groups. Fracture rates among census blocks ranged from 0 to 207 per 1000 children/study period. Logistic regression modeling identified 2 factors (race/education and large families) associated with increased fracture risk. Census variables reflecting African American race, laborer/service industry employment, long-term block group residence, and lower education levels strongly loaded on the race/education factor. The large families factor indicated the children-to-families ratio within the block group. The poverty factor was not independently associated with fracture risk.

Conclusions: Thus, neighborhood characteristics are associated with risk for fractures in children. These results can help inform translational efforts to develop targeted strategies for bone fracture prevention in children.

Key Words: injury, fracture, community methodology

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Childhood bone fractures result in substantial costs and morbidity,[1–3] account for a significant proportion of childhood injuries,[4–8] and are increasing in incidence.[9–12] In patient-level analyses, lower socioeconomic status (SES) is associated with physical inactivity and poor nutrition,[13] both of which are risk factors for deficient bone health and increased fracture risk.[14–18] Lower SES is also associated with lower bone density in adult women[19] and increased adult fracture risk in osteoporosis.[20] On a neighborhood level, Canadian studies have shown that children who live in low-income neighborhoods exercise less and have less healthy diets than those living in more affluent neighborhoods, even after adjusting for family SES.[13] Studies of the effect of such community poverty on childhood fracture risk are limited and have yielded inconsistent results.[7,8] Neighborhood deprivation may increase childhood fracture rates through a variety of factors contributing to physical inactivity, poor nutrition, and subsequent bone health deficits. Additionally, neighborhood deprivation may increase fracture rates due to factors which increase overall injury risk, such as poor surface maintenance of streets/sidewalks and poor design or maintenance of housing and playgrounds.

Published studies have not focused on the effect of neighborhood contextual influences on the incidence of childhood fractures. The overall objective of our study was therefore to evaluate the association between neighborhood characteristics that may be associated with fracture risk and observed pediatric bone fracture rates. We hypothesized that neighborhoods with higher deprivation indices would be associated with higher fracture rates when compared to other neighborhoods with lower deprivation indices.

MATERIALS AND METHODS

Study Design

This was a retrospective cohort study using data from an urban pediatric emergency department (ED) administrative database and the US Census Bureau. This study was approved by the institutional review board at Children's National Medical Center (CNMC).

Study Sample

Billing records were used to identify patient visits for children, ages 0 to 17 years, with self-identified residence in Washington, DC, who were treated for bone fractures in the ED of CNMC between January 1, 2003, and December 31, 2006. This facility is an urban pediatric ED and Level 1 pediatric trauma center with an annual census of more than 70,000 visits during the study period. It is the site of more than 75% of all ED visits made by children in Washington,

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DC.[21] The study included all Washington, DC, census block groups with an estimated greater than or equal to 85% catchment at CNMC.[22] An additional inclusion criterion was a minimum census block group population of 250 persons. Medical record review was performed for individuals with multiple ED visits for fracture to exclude patients with bone mineralization disorders and follow-up visits for the same fracture event.

Geographical Information Systems Analysis

Patient visit addresses were converted to latitudinal and longitudinal point locations using ArcGIS StreetMap USA (Version 9.1, ESRI, Inc, Redlands, Calif). The patient location map layer was overlaid with a layer of census block group polygons; the aggregate count was then computed for each block group using ArcGIS geoprocessing tools. For each census block group, an overall fracture rate was determined using as the numerator the number of cases occurring over the study period and as the denominator the 0 to 17-year-old population according to 2000 census data.

Exploratory Factor Analysis

Exploratory factor analysis, which searches a correlation matrix to identify clusters of variables and represents each cluster (factor) as a linear combination of its constituent variables,[23] was performed using sociodemographic variables extracted from 2000 census data. Thirty-three census variables outlined in Duncan and Aber[24] were used in the analysis and are listed in Table 1. Exploratory factor analysis was performed using SAS (Version 9.1.3; SAS Institute, Cary, NC) with SAS PROC FACTOR using the principal factor extraction option and OBLIMIN rotation. This method of rotating factors, which is the most common nonorthogonal (oblique) solution, was applied to allow factors to be correlated with each other.

Data Analysis

Factor scores were used as predictor variables in the logistic regression model to test the impact of the community constructs on odds of bone fracture for children residing in the census block group. In the modeling, we adjusted for demographic factors, such as age, sex, and race/ethnicity at census block level. Mean age in years, proportion male, and proportion African American at census block level were estimated from our study sample. Data analysis was performed using SAS (Version 9.1.3, SAS Institute).

RESULTS

We identified 4343 fracture visits eligible for inclusion in the study. Of these visits, 4081 (94%) had valid addresses which were successfully converted to point locations. After excluding visits of patients with bone mineralization disorders (n = 15), follow-up visits for the same fracture event (n = 164), visits with invalid medical record numbers (n = 2), and residents of census block groups outside the designated study area (n = 136), there were 3764 fracture visits included in the final analysis. This represents 87% of the original sample. The demographics of these fracture visits are summarized in Table 2. The 3764 fracture visits occurred among 3557 individual patients. During this study period, 3365 (94.6%) individual patients had 1 fracture, 177 (5%) individual patients had 2 fractures, and 15 (0.4%) individual patients had 3 fractures.

Of 433 total census block groups existing in Washington, DC, during the study period, there were 350 census block groups eligible for inclusion in the study based on the catchment and minimal census block group population criteria. A census block group representing a military facility (Bolling Air Force Base) was excluded leaving 349 census block groups in this sample. A map of Washington, DC, with the geographic distribution of the fracture visits is shown in Figure 1. The mean (SD) fracture rate (fractures per 1000 children aged 0 to 17 during the 4-year study period) for the 349 census block groups was 37 (27) with a range of 0 to 207 per 1000 children/study period.

Exploratory factor analysis of the study area and the 33 original variables revealed 7 clusters of sociodemographic variables (neighborhood factors). These factors accounted for 79% of the variation in the original variables. The detailed rotated factor pattern is provided in Appendix Table 1 (Supplemental Digital Content 1, http://links.lww.com/JIM/A15). The standardized factor loadings reported in the table are the standardized slope regression coefficients that would be applied to the original variable values of any census block group to predict that block group's factor score. Higher factor loading indicates that the corresponding observed variables are better indicators of the underlying community constructs. On the basis of the pattern of factor loadings, where items load most strongly on

TABLE 1. Alphabetical List of Demographic and Economic Variables From 2000 Census Data Used in Factor Analysis[24]

Census Block Group Variable
Children-to-families ratio
Gini coefficient of family income
Income categories used in Gini calculation
Index of ethnic diversity
Proportion 16–19 year olds without high school education
Proportion adults unemployed
Proportion adults with less than high school education
Proportion adults with only high school educations
Proportion adults with post–high school education
Proportion black (non-Latino)
Proportion families with at least $67 k/y
Proportion families with low income
Proportion female-headed families with children
Proportion females working
Proportion females working at least half a year
Proportion housing structures with 5+ units
Proportion housing units that are rentals
Proportion males not in labor force
Proportion males working less than 26 wk
Proportion persons 17 years or younger
Proportion persons 65 years or older
Proportion persons foreign born
Proportion persons in same county for 5 y
Proportion persons in same dwelling for 5 y
Proportion persons Latino
Proportion persons not black, white, or Latino
Proportion poor (non-elderly)
Proportion vacant housing units
Proportion white (non-Latino)
Proportion workforce laborers or service occupations
Proportion workforce professionals/executives
Ratio of persons to housing units
Two-parent families-to-child ratio

TABLE 2. Demographics of Fracture Visits in the Washington, DC, Study Population

Variable	Overall (n = 3764 Visits)
Sex, %	
Male	66.8
Female	33.2
Age, mean (SD), y	9.5 (4.5)
Race/ethnicity, %	
Black	85.9
Hispanic	8.8
White	2.7
Unknown	1.7
Other	0.9

1 factor, and much weakly on the other factors, neighborhood factors were defined and named.

Each of these 7 neighborhood factors and the variables with standardized factor loadings greater than or equal to 0.40[25] are provided in Table 3. Briefly, the second factor represents the neighborhood characteristic of poverty and unemployment. It is a relatively independent construct of the first factor (race/education); variables reflecting poverty and unemployment are primarily loaded on the second factor rather than cross-loading on the race/education factor. Factors are ordered according to the importance of the amount of variation in the original data that each factor represents. For instance, the race/education factor accounted for 37.8% of the input information and the poverty/unemployment factor accounted for 15.2% of the input information.

The results of the logistic regression model are presented in Table 3. The race/education factor and the large families factor are significantly associated with increased fracture risk and the seniors factor is significantly associated with decreased fracture risk. Because the factor scores were standardized and represent relative positions of individual scores in a distribution, the relative positions should not be affected by a change in metric or coding of variables. Standardized factor scores were treated as continuous independent variables in the model. The slope coefficients of factors are interpreted in the same way of interpreting any other continuous independent variables. A 1-unit increase in the race/education factor score or the large families factor score in a census block group is associated with a 27% or 11% increase in the odds of fracture, respectively, for resident children in the block. Similarly, a unit increase in the seniors factor score in a census block group is associated with a 9% decrease in odds of fracture for resident children in the block.

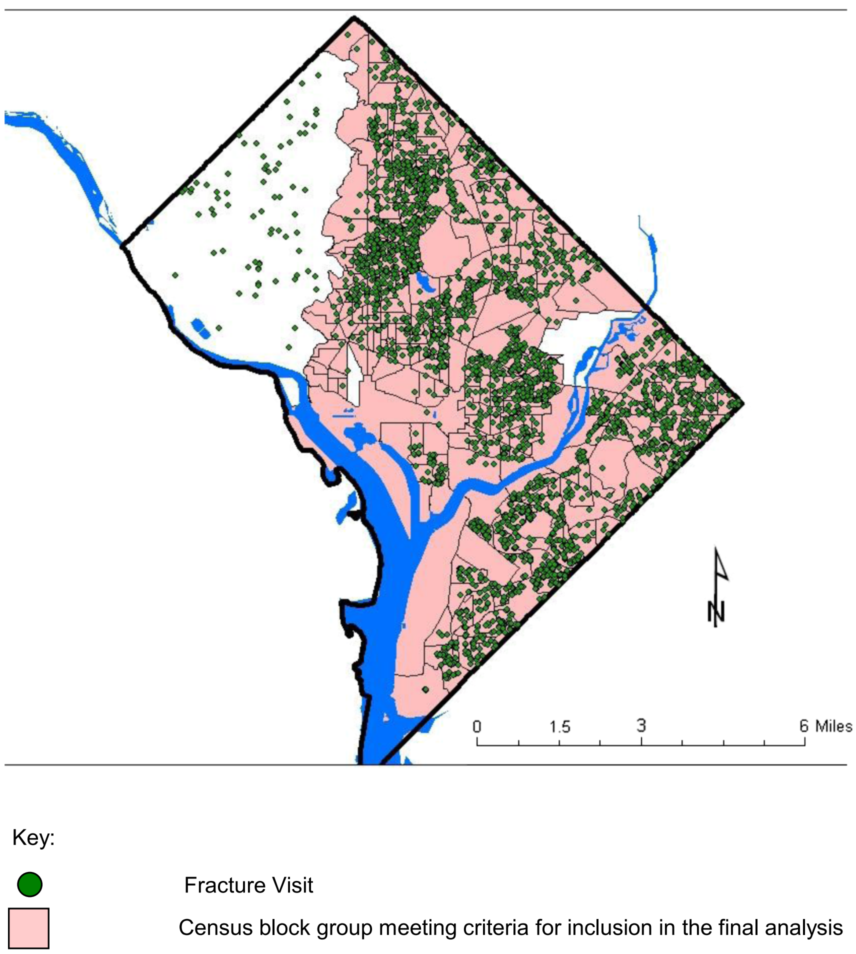

FIGURE 1. Map of Washington, DC, with geographic distribution of fractures treated in the ED at Children's National Medical Center, 2003–2006.

DISCUSSION

Approximately 50% of children will fracture a bone, and nearly 40% of this group will experience future childhood fractures.[26] A history of a prior fracture is associated with an increased risk of another fracture during childhood.[27] Hence, a subset of the pediatric population seems to be at increased risk for fractures.

Person-level factors related to deficiencies in bone health are associated with increased risk of fracture in children. Specifically, elevated fracture risk in otherwise healthy children may be a function of lower bone mineralization associated with physical inactivity and poor nutrition[14–18] as well as environmental risk factors for vitamin D deficiency, such as limited sun exposure.[28,29] Deficient bone health in childhood negatively impacts adult bone mineralization and may increase the risk of adult osteoporosis and related fracture.[30–32]

Person-level factors are not sufficient to account for all population variation in risk, however. Both person-level and group-level factors should be considered to understand the causes of disease in individuals. Research on the determinants of health has evolved by expanding beyond a focus on individual risk factors to include neighborhood contextual influences.[33–35] These studies measure aspects of the neighborhood environment thought to play a role in the health condition of interest, and test for community effects independently of effects measured at individual and household levels. In addition to the person-level factors associated with increased fracture risk discussed previously, neighborhood level factors, such as those impacting physical activity level, nutritional status, and/or safety and injury risk, may also contribute to fracture risk in children. Neighborhood contextual effects have been found for many diseases, including adult hip fracture.[36]

Our analysis demonstrates that specific neighborhood characteristics are significantly associated with risk patterns for childhood bone fracture. This study is novel in conducting an exploratory analysis to assess the effect of neighborhood factors on bone fracture risk in a US pediatric population. In this study, neighborhood indicator variables were extracted from census data and factor analysis was conducted at a census block group-level.

There are few other published studies of the effect of community poverty on childhood fracture risk and these studies have yielded inconsistent results.[7,8] Lyons et al[7] compared incidence rates for childhood fractures in South Wales, UK, by electoral ward quarters based on Townsend scores, a measure of deprivation which uses 4 demographic census variables reflecting affluence or deprivation of the area.[37] Fracture rates for all activities were similar across the quarters. However, affluent areas had significantly higher rates of sports-related fractures, whereas poorer areas had significantly more assault-related fractures. Stark et al[8] analyzed childhood fracture rates by deprivation level within postcode sectors in Glasgow, UK. Three deprivation levels (affluent, middle, and deprived) were identified using 29 demographic variables obtained from census data. Their analysis showed that children living in deprived areas had significantly higher fracture rates than those in affluent areas.

Contrary to our primary hypothesis and similar to Lyons et al,[7] we did not find a significant association between fracture rates in children and neighborhood poverty in our study

TABLE 3. Neighborhood Factors, Variables With Standardized Factor Loadings Greater Than or Equal to 0.40, and Adjusted Odds Ratios* of Factor Scores as Predictors of Fracture Risk in the Washington, DC, Study Population

Neighborhood Factor	Variables From Table 1 With Standardized Factor Loadings ≥ 0.40 Listed in Descending Order of Value	Adjusted Odds Ratio* (95% Confidence Interval)
F1-Race/education	• Proportion workforce laborers or service occupations	1.27 (1.14–1.42)
	• Proportion adults with only high school educations	
	• Proportion persons in same county for 5 y	
	• Proportion black (non-Latino)	
	• Proportion adults with less than high school educations	
	• Proportion persons in same dwelling for 5 y	
	• Proportion female-headed families with children	
	• Proportion persons 17 y or younger	
F2-Unemployment/poverty	• Proportion adults unemployed	0.95 (0.89–1.01)
	• Proportion poor (non-elderly)	
	• Proportion males working less than 26 wk	
F3-Immigrants	• Proportion persons Latino	0.96 (0.90–1.02)
	• Proportion persons foreign born	
	• Index of ethnic diversity	
F4-Rentals	• Proportion housing units that are rentals	1.02 (0.97–1.08)
	• Proportion housing structures with 5+ units	
	• Proportion families with low income	
	• Gini coefficient of family income	
F5-Large families	• Children-to-families ratio	1.11 (1.06–1.18)
	• Proportion males not in labor force	
F6-Crowding	• Ratio of persons to housing units	1.04 (0.98–1.11)
F7-Seniors	• Proportion persons 65 years or older	0.91 (0.86–0.96)
	• Proportion males not in labor force	

*Adjusted for mean age, sex composition, and proportion black race at census block level using individual level data from our study sample population. Our study design does not allow differentiation of a specific mechanism or mechanisms for why neighborhood poverty may not be associated with fracture risk in children. We speculate that this may involve differential exposures to risk and/or access to resources which may balance fracture risk in this setting. For instance, such findings could reflect the decreased physical activity levels present in children who live in poor neighborhoods.[13] Although physical inactivity may be detrimental to bone mineral density status,[14–18] which would theoretically increase fracture risk, it may also be protective by decreasing exposure to falls and fall-related injury.

It is challenging to compare our study findings directly to these UK-based studies for several reasons. First, each study used different census variables and geographic units to define neighborhood deprivation. Second, it is likely that there are important differences among the populations of Washington, DC; South Wales; and Glasgow. Finally, the UK-based studies did not seem to control for race. Race and SES are often closely linked and there are several reasons why race, and specifically African American race, may contribute to fracture risk in children. These reasons include higher rates of obesity[38–40] and poor dietary intake of calcium,[41,42] which will further be discussed later.

Our study identified 2 neighborhood factors (race/education and large families) associated with increased risk for childhood bone fracture. Census variables reflecting African American race, laborer/service industry employment, long-term block group residence, and lower education levels strongly loaded on the race/education factor. African American children may be a vulnerable subset of the pediatric population at higher risk of fracture due to both environmental and genetic factors. Risk factors for childhood fractures, such as obesity[38–40] and calcium-deficient diets[41,42] are prevalent among African American children. Genomic studies suggest that genetic risk for fracture reflects an interaction between vitamin D receptor polymorphisms and the existence of calcium and vitamin D deficiencies for which this population may be at increased risk.[43,44] Similarly, darker skin pigmentation is a risk factor for vitamin D deficiency which is associated with decreased bone mineral density, another risk factor for fracture.[28,29] One recent case series demonstrated an unusually high prevalence of vitamin D insufficiency (59%) in a population of healthy African American children with forearm fractures.[45]

The large families factor was also associated with increased fracture risk and indicates the children-to-families ratio within the block group. Such a ratio may reflect large family size. We believe that this factor may serve as a proxy for poor child supervision. Decreased parental supervision is associated with increased risk for injury and may also be more prevalent as the number of children increases.[46] Similarly, sibling supervision (which may occur more commonly in larger families) is also associated with further increase in risk.[47]

The seniors factor was significantly associated with decreased fracture risk and reflects neighborhoods with higher populations of senior citizens. We believe that this observation, in contrast to the large families factor, may indicate an environment with increased supervision due to the increased presence of adults. As discussed previously, less supervision is associated with increased injury risk, and larger adult populations may similarly demonstrate a protective effect.

This study has several limitations. First, the generalizability of the study may be limited by the single city design. Second, because patients were identified using ED billing records, it is possible that eligible patients were not included in the study sample. Third, the address of the patient at the time of the ED visit was used in the analysis; we have no information on the duration of the patient's residence at that address and/or subsequent relocation from the original census block group. Similarly, we relied on the accuracy of the address provided by the patient's guardian at the time of the ED visit and did not pursue further confirmation of residence. Fourth, it is possible that alternative methodological approaches could yield different results. As an example, the findings may not be identical to those we report in the current study if the factor analysis was conducted at the individual level instead of at the census block group level. Finally, this analysis does not distinguish between fractures resulting from either unintentional or intentional injury. It is notable that a subsequent subanalysis of this fracture cohort with detailed medical chart review of 929 forearm fracture cases[48] showed that all were clinically attributed to unintentional injury. For this reason, we suspect that intentional injury reflected a very small proportion of this fracture cohort.

In conclusion, specific neighborhood characteristics, including race/education and large family size, are significantly associated with risk patterns for bone fracture in our study population. Although this study does not specifically address prevention, these results are an important first step toward informing potential interventions to prevent future fractures in children. Application of these analysis techniques in the setting of injury research is a novel approach to better understanding the role of neighborhood factors in child injury risk and incorporating this knowledge into intervention strategies. Subsequent efforts to elucidate the causative mechanisms underlying these associations would further contribute to the development of future targeted interventions, which may decrease fracture rates in childhood.

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