Neighborhood Risk Factors for Pediatric Fall-Related Injuries: A Retrospective Analysis of a Statewide Hospital Network

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Abstract

Background: Falls represent the leading cause of nonfatal unintentional injuries among children in the United States. Although unintentional injury risks have been studied, neighborhood impact on falls remains underexplored. This study examined the association of neighborhood attributes with rates of fall-related injuries.

Methods: This is a retrospective study of children who presented to emergency departments within a statewide hospital network for fall-related injuries between 2005 and 2014. Patients' home addresses were geocoded to identify US Census block groups (BGs). Average annual fall rates were computed for each BG. A neighborhood risk index was constructed using 8 socioeconomic BG measures (education, crowding, vacancy, renter occupancy, poverty, family structure, race/ethnicity, and housing age). Public outdoor recreational facilities in each BG were enumerated. Linear regression analysis was used to assess the association of neighborhood risk and recreational facilities with fall rates.

Results: From 2005 to 2014, there were 139,986 unintentional injury emergency department visits; of these, 42,691 (30%) were for falls. The largest proportion of falls were among males (58%), children ages 1 to 4 years (39%), non-Hispanic whites (59%), and children with public health insurance (53%). Higher quintiles of neighborhood risk were associated with higher annual fall rates compared to the lowest quintile of risk: quintile 2, $\beta = 0.44$, 95% confidence interval (CI), 0.20−0.68; quintile 3, $\beta = 0.85$, 95% CI, 0.61−1.10; quintile 4, $\beta = 1.11$, 95% CI, 0.85−1.37; quintile 5, $\beta = 1.57$, 95% CI, 1.29−1.85. The presence of public outdoor recreational facilities was not associated with fall rates ($\beta = 0.01$; 95% CI, −0.14 to 0.15).

Conclusion: Neighborhood-level socioeconomic characteristics are associated with higher fall-related injuries. Injury prevention programs could be tailored to address these neighborhood risks.

Keywords: child health; falls; pediatric injury; spatial analysis

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What's New

We developed an index to study the association between neighborhood attributes and pediatric fall-related injury rates. The index, comprised of neighborhood variables including education, crowding, vacancy, renter occupancy, poverty, family structure, race/ethnicity, and housing age, was associated with a higher number of fall-related injuries.

Pediatric falls represent the leading cause of unintentional nonfatal injuries in children in the United States, resulting in substantial medical costs and morbidity with over 2.8 million emergency department (ED) visits incurring up to $7 billion in medical costs in 2010 alone.[1,2] The most common cause and location of pediatric falls differ by age group; however, falls commonly occur in the home and on playgrounds, with greater injury severity being associated with increasing height of the fall.[3,4] Severe injuries that result in hospital admission include head and musculoskeletal injuries.[5,6] Although public health efforts toward fall prevention have succeeded in reducing fatalities from window falls,[7,8] falls are still a significant cause of childhood injury and morbidity.[1,6,9]

Previous research on unintentional childhood injuries has demonstrated that injuries are disproportionately higher in certain socioeconomic groups and neighborhoods. In neighborhood-level analyses, it is commonly reported that children living in densely concentrated areas of racial minorities reflecting African American race and areas of poverty experience unintentional injuries at

higher rates than other children.[10–15] In patient-level analyses, male gender, income, renter-occupied housing, and parental education level are also associated with child injury.[15–18] Although there is extensive literature on overall unintentional injuries, the few studies that have examined risk factors for falls specifically are more than 10 years old and used few sociodemographic or neighborhood variables.[11,18,19] The lack of recent population-based studies of pediatric falls makes it challenging to design effective interventions for fall injuries. Moreover, external causes of unintentional falls are commonly associated with playgrounds or recreational sports; yet, no studies to date have examined the association between access to recreational facilities, where children can engage in play and sports-related activities, as a neighborhood characteristic and fall-related injury rates.[4,20]

Our objective was to study the burden of pediatric falls and the association between neighborhood attributes with rates of fall-related injuries. We hypothesize that neighborhoods with public outdoor recreational facilities and higher measures of poverty and risk factors for unintentional injuries will have a higher burden of pediatric fall-related ED visits.

Materials and Methods

Study Design

Our study was a retrospective cohort study using data from a statewide hospital network in Rhode Island, from the US Census Bureau, and from the Rhode Island Geographic Information System (RIGIS). This study was approved by the Rhode Island Hospital Institutional Review Board.

Data Sources

The statewide hospital network used in this study provides the majority of pediatric ED services in Rhode Island and includes the state's only children's hospital. The network accounts for 90% of the state's pediatric inpatient stays and more than two-thirds of all pediatric ED visits. ED visits made by children ≤ 17 years of age from 2005 through 2014 were included. We categorized visits based on International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), supplementary E-codes that reflected external causes of injury, poisoning, or other adverse events. A visit with any E-codes between E880 and E888 was defined as an unintentional fall-related injury visit; a visit with any E-code between E800 and E849, E890 and E899, or E916 and E929 was defined as an unintentional injury visit not related to a fall. Visits with no E-code or ICD-9-CM injury code were defined as non-injury visits.

The variables used to characterize patients' neighborhoods were obtained from the 2010–2014 American Community Survey (ACS) and the 2010 US Census (Census). Patients' home addresses obtained from the hospital network were geocoded using ArcGIS (Esri, Redlands, Calif) to identify the Census block group (BG). Patients whose reported addresses were located outside of Rhode Island or were in BGs with fewer than 20 children in the 2010 Census were excluded from this study.

Information regarding Rhode Island's outdoor public recreational facilities was retrieved from RIGIS, an open data platform that distributes geospatial data contributed by government and private organizations for the state of Rhode Island. All public outdoor recreational facilities maintained by state and local governments in Rhode Island were reported by the Rhode Island Department of Environmental Management (http://www.rigis.org/data/SCORP). This dataset was last updated in 2014 and excludes private facilities, indoor facilities, and fee-based outdoor facilities, as they are not owned by the public.

Independent Variables

Eight BG-level socioeconomic attributes were obtained from the ACS and Census to characterize BGs and determine their association with falls. These neighborhood socioeconomic variables include the following measures of poverty and risk factors previously associated with unintentional childhood injury in prior studies: proportion of families with incomes below 100% of the federal poverty level (ACS),[11,21,22] proportion of renter-occupied homes (ACS),[11,17,23] proportion of housing units built before 1950 (ACS),[10,11] proportion of single-parent households (ACS),[15,24–26] proportion of the population older than 25 years who were not high-school graduates (ACS),[10,15,21,25] proportion of vacant homes (ACS),[13,27,28] proportion of the population of household families with ≥1 person per room (ACS),[23] and proportion of the population that was non-white (Census).[10,11,21,28] We computed quintiles for each variable and summed these to create a neighborhood risk index (NRI) for each BG, which we then categorized by quintiles, with higher quintiles signifying increased risk.

We defined a public outdoor recreational facility as any playground, field intended for sports, court intended for sports, skate park, ice rink, hockey rink, or track. Fishing, boating, beaches, trails, and hunting facilities were excluded, as these were not considered age-appropriate forms of play for this study population. We computed the count of public outdoor recreational facility categories that met our inclusion criteria for each BG. BGs were categorized as having at least 1 recreational facility versus none.

Outcome measure

The average annual count of fall-related ED injury visits was computed for each BG. This was divided by the 2010 Census population count of children ≤ 17 years of age, and the resulting rate was multiplied by 100 to obtain the average annual fall-related injury rate.

Statistical Analysis

Summary statistics for ED visits were computed as frequencies and percentages based on age, sex, race/ethnicity, source of payment, visit disposition, and injury severity.

Injury severity was determined by using a mapping function (https://ideas.repec.org/c/boc/bocode/s457028.html) and ICD-9-CM diagnosis codes to generate body-region-specific Abbreviated Injury Scale (AIS) scores for trauma injuries, ranging from 1 (minor) to 6 (maximal). The score of the most severe injury is considered the maximum AIS score. Previous studies have validated the process of mapping diagnosis codes to generate anatomic injury scores.[29,30] ICD-9-CM diagnosis codes with insufficient detail to be mapped were assigned an AIS score of 9 and defined as unknown severity. Because AIS scoring does not apply to injury-related visits without trauma, such as visits with E-codes but no injury-related ICD-9-CM codes, these visits were assigned an AIS severity score of 0. We then categorized visits with a maximum AIS score of 1 or 2 as experiencing minor to moderate injury and 3 to 6 as experiencing serious to maximal injury to characterize our study sample.[29]

For neighborhood-level analyses, we used multivariable linear regression to model average annual fall rates of BGs based on quintiles of NRI and the presence of public outdoor recreational facilities. In the modeling, we adjusted for demographic factors such as average age and sex at the BG level. Mean age in years and proportion male at the BG level were estimated from our study sample. All statistical analyses were conducted using Stata version 14.0 software (StataCorp, College Station, Tex), and all tests were evaluated using an overall significance level of $P < .05$.

RESULTS

In our study cohort, out of 139,986 unintentional injury visits during the study period, 42,691 visits (30.5%) were for fall-related injuries. The largest proportion of fall-related ED visits were among male children (58.1%), children ages 1 to 4 years (39.3%), non-Hispanic white children (59.2%), and children with public health insurance (52.6%). The large majority of fall-related ED visits did not result in admission (97.1%), and most injuries were minor to moderate (95.4%). The demographic characteristics of children presenting for unintentional fall-related injuries are summarized in Table 1.

Patients resided in 809 of the 815 BGs in Rhode Island. Twelve of these 809 BGs had a 2010 Census population count of fewer than 20 children and were not included in the multivariable analysis. The average annual fall rate (falls per 100 children ages 0 to 17 per year) for the 797 BGs was 1.94 (± standard deviation 1.17) with a range of 0 to 8 per 100 children per year. Most fall-related visits were concentrated in urban areas and around hospital locations. The lowest quintile neighborhoods had more public outdoor recreational facilities than the highest quintile neighborhoods (304 and 175, respectively). Geographic Information System maps of BGs by NRI quintiles, rates of fall-related injuries per 100 children per year, hospital locations, and locations of recreational facilities are shown in the Figure.

As summarized in Table 2, the top 5 most common mechanisms of all unintentional injuries during the study

Table 1. Demographic Characteristics of Emergency Department Visits for Fall-Related Injuries, Non-Fall-Related Injuries, and Non-Injuries Among Children Between 2005 and 2014

Patient Characteristics	Fall-Related Injury Visits (N = 42,691) n (%)	Non-Fall-Related Injury Visits (N = 97,295) n (%)	Non-Injury Visits (N = 333,357) n (%)
Age, years			
<1	3231 (7.6)	4046 (4.2)	63,454 (19.0)
1–4	16,797 (39.3)	24,800 (25.5)	114,902 (34.5)
5–9	10,312 (24.2)	20,842 (21.4)	65,024 (19.5)
10–14	8675 (20.3)	27,224 (28.0)	50,993 (15.3)
15–17	3676 (8.6)	20,383 (20.9)	38,984 (11.7)
Sex			
Male	24,818 (58.1)	56,222 (57.8)	171,896 (51.6)
Female	17,873 (41.9)	41,073 (42.2)	161,461 (48.4)
Race/ethnicity			
Hispanic	10,426 (24.4)	24,272 (24.9)	112,882 (33.9)
Non-Hispanic black	4416 (10.3)	12,727 (13.1)	44,358 (13.3)
Non-Hispanic white	25,283 (59.2)	54,354 (55.9)	153,514 (46.0)
Other or unknown race	2556 (6.0)	5942 (6.1)	22,603 (6.8)
Payer type			
Public	22,454 (52.6)	52,513 (54.0)	217,393 (65.2)
Private	18,506 (43.3)	40,034 (41.1)	99,845 (30.0)
Self-pay/none	1731 (4.1)	4748 (4.9)	16,119 (4.8)
Discharge from emergency department			
Emergency department visit only	41,454 (97.1)	89,199 (91.7)	287,500 (86.2)
Emergency department visit and admitted	1026 (2.4)	5533 (5.7)	32,409 (9.7)
Admitted only	211 (0.5)	2563 (2.6)	13,448 (4.0)
Maximum Abbreviated Injury Scale scores			
0 (no trauma injury)	1472 (3.4)	23,660 (24.3)	329,537 (98.9)
1–2 (minor to moderate)	40,718 (95.4)	71,004 (73.0)	NA
3–6 (serious to maximal)	495 (1.2)	822 (0.8)	NA
9 (unknown severity)	6 (0.1)	1809 (1.9)	NA

*Visit-level data may have multiple observations per child.

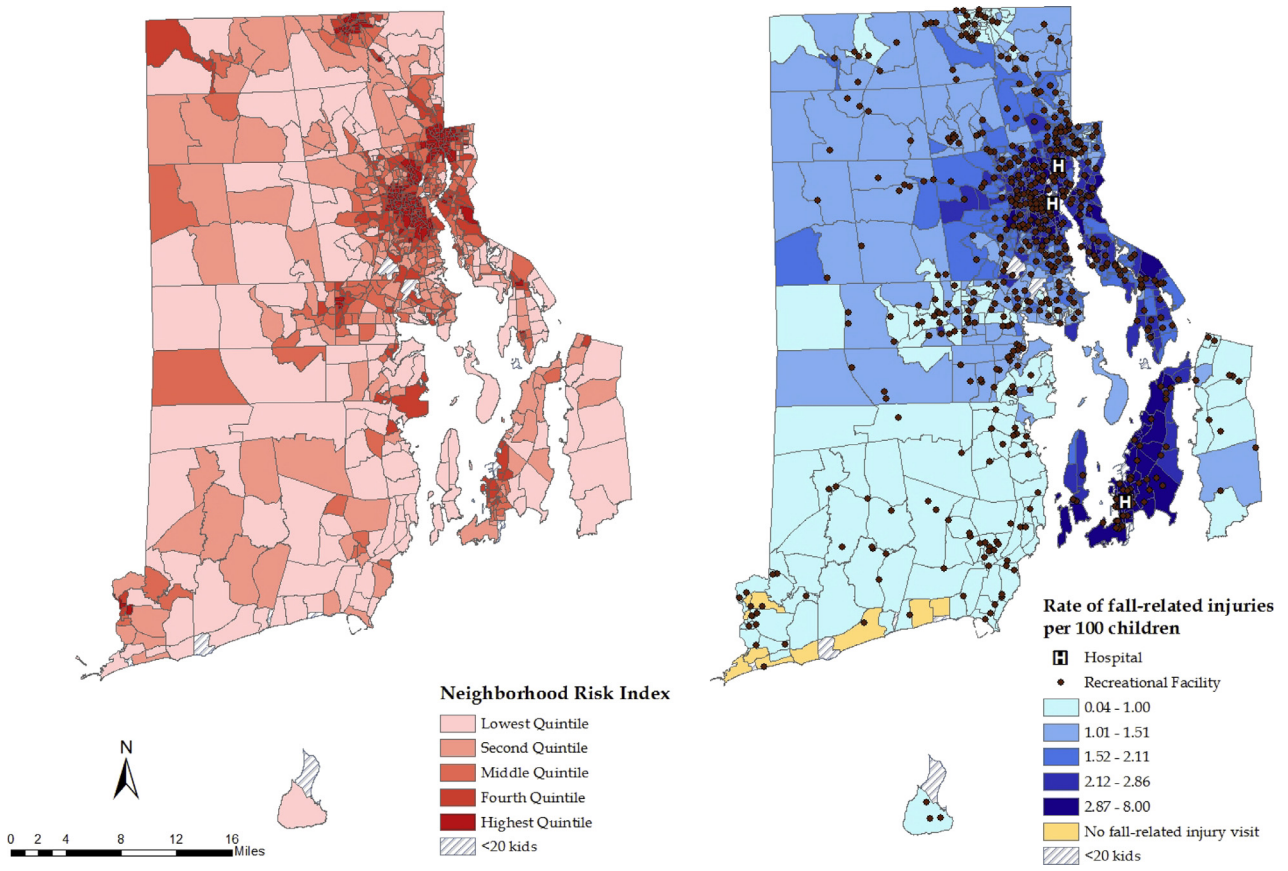

Figure. *Geographic Information System maps of census block groups of the (**A**) geographical distribution of neighborhood risk index quintiles and (**B**) average annual rates of pediatric falls per 100 children and locations of recreational facilities. Values in the indicated ranges are represented using a shaded scale. Locations of hospitals are represented by the indicated symbol. Dots represent recreational facilities.*

period in NRI quintile 1 neighborhoods (lowest risk) and quintile 5 neighborhoods (highest risk) are similar, with higher counts of injuries occurring in quintile 5 neighborhoods. The top 5 mechanisms of fall-related injuries in NRI quintiles 1 and 5 are identical; however, the counts of falls are also significantly higher in quintile 5. The highest proportion of falls was coded other and unspecified fall, followed by fall from one level to another; accidental fall on same level from slipping, tripping, or stumbling; fall on or from stairs or steps; and fall on same level from collision, pushing, or shoving.

All 8 variables used in the NRI, when compared with BGs in the lowest quintile to those in the highest quintile, were associated with fall rates in both unadjusted and adjusted linear regression models (results not shown). As shown in Table 3, controlling for average age and proportion male, BGs with higher levels of neighborhood risk had higher average annual fall rates per 100 children. Public outdoor recreational facilities were not associated with average annual fall rates.

DISCUSSION

This study demonstrated that neighborhoods with higher levels of socioeconomic risk factors, as measured by the NRI, are associated with higher average annual rates of unintentional pediatric fall-related injuries. Conversely, no association was observed between the presence of neighborhood recreational facilities and average annual fall rates. This association suggests that neighborhood characteristics may be important risk factors for childhood falls.

Table 2. Top 5 Mechanisms of Unintentional Injury-Related Emergency Department Visits by Neighborhood Risk Index Quintiles 1 and 5

Neighborhood Risk Index Quintile 1 (n = 170)			Neighborhood Risk Index Quintile 5 (n = 168)		
Rank	Mechanism	N = 20,538 (% Injury Visits)	Rank	Mechanism	N = 51,022 (% Injury Visits)
1	Fall	6584 (35%)	1	Fall	14,689 (34%)
2	Struck by/against	4007 (21%)	2	Struck by/against	7510 (17%)
3	Unspecified	2762 (14%)	3	Motor vehicle traffic	4573 (10%)
4	Overexertion	1099 (6%)	4	Unspecified	3051 (7%)
5	Other not elsewhere classifiable	946 (5%)	5	Other not elsewhere classifiable	2981 (7%)

Table 3. Results of Multivariable Linear Regression Analysis for Average Annual Fall Rate Based on Neighborhood Risk Index Quintile and Number of Recreational Facilities per Census Block Group

	Average Annual Fall Rate*		
	β Coefficient	95% Confidence Interval	*P* Value
Neighborhood risk index quintile			
1 (low risk)	Ref	...	...
2	0.44	0.20–0.68	.00
3	0.85	0.61–1.10	.00
4	1.11	0.85–1.37	.00
5 (high risk)	1.57	1.29–1.85	.00
Recreational facilities			
None	Ref	...	...
At least 1	0.01	−0.14 to 0.15	.99

*Adjusted for average age and number of male children per census block group estimated from our study sample.

To our knowledge, this is the first study of the association between access to recreational facilities and rates of childhood falls on a population level. Access to recreational facilities, to our surprise, was not associated with fall-injury rates, despite ED surveillance studies in the United States reporting recreation and playgrounds as common causes of fall-related injuries.[4,20] One possible explanation for this finding is that other factors not measured in our study such as safety and quality of recreational facilities may moderate fall injury risk rather than access to recreational facilities. Previous studies investigating playgrounds in large US cities have found that neighborhoods with a larger percentage of African American children and population living below the poverty level had fewer playgrounds, but a greater proportion of those playgrounds failed safety inspections compared to those in other neighborhoods; however, any association with injury rates was not investigated.[31,32] Similarly, in our study sample, higher quintile neighborhoods had fewer public outdoor recreational facilities. One potential explanation for having fewer recreational facilities in areas with higher fall-related injury rates is that children have fewer options and opportunities for safe areas to play than those who live in lower quintile neighborhoods. Exploration into the association of neighborhood quality and safety of recreational facilities with fall injury rates is needed to understand potential factors contributing to fall injury disparity.

Our findings on socioeconomic and neighborhood indicators for risk of childhood falls are consistent with the few population-based studies that have examined falls. Using hospital discharge information to study falls and burns, Shenassa et al[11] used concentration of poverty, concentration of African American population, percentage of owner-occupied housing, and percentage of housing built before 1950 as independent neighborhood variables and found that children residing in neighborhoods with higher concentrations of poverty, minorities, and old housing had higher fall rates, but owner occupancy was protective. Similarly, in a study conducted in Ontario, Canada, by Faelker et al,[18] children in neighborhoods with increasing percentages of individuals living in poverty experienced more falls. Although the aforementioned studies analyzed neighborhood variables individually for risk of childhood falls, our methodology was different in that we combined variables to create a composite risk index that includes other measures of area-level socioeconomic status and injury risk. We used a composite index because using multiple variables to create a composite index is a more sensitive marker for the combined effect of social determinants on injury risk than using single indicators alone.[22] Although the use of an index as a proxy measure for socioeconomic status is limited in the United States,[33–35] our methodology is not unprecedented. Several geographic-based indices have been developed, validated, and widely used in Western Europe as a standardized measure to characterize neighborhood disadvantage, particularly as related to adult or child health outcomes.[36–39] Therefore, the use of indices has been shown to be valuable in measuring neighborhood risk in other contexts.

Although causality cannot be determined based on our observational analysis, mechanisms by which each variable from the NRI may predispose children to falls can be postulated. The socioeconomic variables from the NRI including neighborhoods with a large proportion of families that are living below 100% of the federal poverty level and proportion of adults who are not high-school graduates may contribute to fall injury risk in children due to limited access to safe areas for play in low-income neighborhoods and poor maintenance of playgrounds and recreational facilities.[31,32] In addition, purchasing fall safety equipment is a barrier for adopting preventive interventions according to previous studies, and poverty can make it cost prohibitive for families.[40]

Neighborhood housing variables in the NRI, measured by the proportion of renter-occupied homes, homes built before 1950, crowding, and vacant homes, are indicators of socioeconomic decline of a neighborhood or potentially injury-related structural deficiencies. Istre et al[41] demonstrated that older homes were not required to comply with new building codes regarding windows and balcony rails. As a result, they found that older homes with widely spaced balcony rails and windows positioned low to the ground contributed to more falls. Renters, on the other hand, have added challenges when trying to improve structural deficiencies in their homes because of poorly enforced tenant protection laws.[42]

The proportion of single-parent households was another neighborhood variable we included in our NRI. Primary caregiver or parental supervision plays a protective role in preventing childhood injuries.[43] According to the literature, children in single-parent households spend less time under the supervision of their primary caregiver than children in 2-parent households.[44] The mechanism by which we postulate that children in neighborhoods with larger proportions of single-parent families are at risk for more fall-related injuries is that single parents may not spend as much time supervising as 2-parent families because of the fewer number of primary caregivers in the home. Another potential mechanism relates to facing economic burden: single-parent families are 5 times more likely to live in poverty than 2-parent families.[45] Single-parent families living in poverty can contribute to fall risk due to the aforementioned mechanisms in which poverty impacts a child's environment and access to fall safety equipment.

Finally, the proportion of non-whites was also included in the NRI. After controlling for socioeconomic status, this variable has been associated with greater risk of childhood injuries in many studies; yet, there is no consensus in the literature for how this variable is presumed to increase the risk of childhood injuries.[5,11] We speculate that a combination of socioeconomic characteristics of neighborhoods with greater concentrations of racial minorities likely contributes more to fall injury risk than minority status itself. A report from The Century Foundation demonstrated that over 25% of African Americans and 17.4% of Hispanics live in high-poverty neighborhoods compared to 7.5% of non-Hispanic whites, indicating that minorities are much more likely to live in poor neighborhoods than whites.[46] Moreover, according to a qualitative study, African Americans living in a largely concentrated neighborhood of minorities report poor housing and neighborhood conditions in addition to lack of access to services that are meant to remedy maintenance problems.[47] Race alone is unlikely to explain the observed disparity in child injury risk; therefore, complex interactions of other characteristics in neighborhoods with concentrated areas of racial or ethnic minorities likely contribute to the observed association with falls.

Strengths and Limitations

This is the first population-based study to apply a composite index to examine the association of neighborhood characteristics with rates of childhood falls. We present the most recent data on pediatric falls using a large sample size from a statewide hospital network. Our study sample is demographically diverse, potentially making it generalizable to other US states, and our study design accounts for several known confounders.

Our findings are subject to limitations. First, our study sample was limited to children who attended an ED within the statewide hospital network and excluded children with visits to physician offices or out-of-network facilities; thus, fall-related injury visit rates are underestimated. However, our findings remain valuable as they represent over two-thirds of all pediatric ED visits and the only children's hospital in the state, representing over 90% of pediatric admissions. Second, the hospital network documents patients' addresses but does not record where the fall injury occurred. The location of where the injury occurred may differ significantly from the location of residence in terms of the variables used in our study; however, a patient's home address is the most consistently obtained information available for geographic-based studies. Future studies are needed to map actual injury location and the patient's home address to determine if they differ significantly. Third, the dataset that was used for the count and locations of public outdoor recreational facilities was last updated in 2014, whereas our study sample included ED visits from 2005 to 2014. Although changes in recreational facilities could have occurred during the study period, datasets for previous years were unavailable. Finally, it must be noted that associations found on the ecologic level do not necessarily determine causation on the individual level. Despite these limitations, we believe that these data provide important surveillance information that identifies neighborhoods in need of targeted efforts to prevent pediatric fall injuries.

Conclusions

Results from this study provide the most recent data on childhood fall injuries. We demonstrated that neighborhood-level sociodemographic variables, as measured by our neighborhood risk index, are associated with higher fall-related injuries. We also identified neighborhoods with a higher proportion of fall-related injuries. Contrary to our hypothesis, access to recreational facilities was not associated with falls. Further research on the causality of these associations and interventions that are effective in addressing the morbidity and disparity related to neighborhood-level sociodemographic risks is warranted.

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