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Local vs. National: Epidemiology of Pedestrian Injury in a Mid-Atlantic City

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Abstract

Objective—Understanding pedestrian injury trends at the local level is essential for program planning and allocation of funds for urban planning and improvement. Because we hypothesize that local injury trends differ from national trends in significant and meaningful ways, we investigated city-wide pedestrian injury trends to assess injury risk among nationally-identified risk groups, as well as identify risk groups and locations specific to Baltimore City.

Methods—Pedestrian injury data, obtained from the Baltimore City Fire Department, were gathered through EMS records collected from January 1 to December 31, 2014. Locations of pedestrian injuries were geocoded and mapped. Pearson Chi-square Test of Independence was used to investigate differences in injury severity level across risk groups. Pedestrian injury rates by age group, gender, and race were compared to national rates.

Results—A total of 699 pedestrians were involved in motor vehicle crashes in 2014—an average of two EMS transports each day. The distribution of injuries throughout the city did not coincide with population or income distributions, indicating there was not a consistent correlation between areas of concentrated population or concentrated poverty and areas of concentrated pedestrian injury. Twenty percent (n=138) of all injuries occurred among children age 14, and 22% (n=73) of severe injuries occurred among young children. The rate of injury in this age group was five times the national rate (IRR= 4.81, 95% CI=(4.05, 5.71)). Injury rates for adults 65 were less than the national average.

Conclusions—As the urban landscape and associated pedestrian behavior transform, continued investigation of local pedestrian injury trends and evolving public health prevention strategies are necessary for ensuring pedestrian safety.

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Keywords

pedestrian injury; safety; descriptive epidemiology; injury surveillance

INTRODUCTION

Pedestrian injuries and fatalities nationwide have increased over the last five years (National Center for Statistics and Analysis 2016). Studies examining this increase have been focused at the national level, and localized studies of pedestrian injury have been scarce. Data on national trends in pedestrian injury are useful for focusing research questions and identifying risk groups for directed inquiry; however, they may lack specificity when describing risk factors unique to individual metropolitan areas as national data stratified by urbanicity is currently unavailable. For example, a study of pedestrian fatality in Atlanta found that Hispanics had more than twice the risk of pedestrian fatality compared to the national fatality risk among Hispanics, and older adults had significantly lower fatality risk compared to their national counterparts (Beck et al. 2007).

Aside from a handful of studies on specific pedestrian injury risk groups, including children under age 14 (DiMaggio and Durkin 2002) and older adults over age 65 (Nicaj et al. 2006), and several studies investigating injury severity predictors (Moudon et al. 2011; Pour-Rouholamin and Zhou 2016), few studies have explored local trends in pedestrian injury. We could find no studies in the peer-reviewed literature that provided a description of pedestrian injury localized to a specific city or region in the United States using data collected within the past 10 years. Furthermore, national trend data stratified by urbanicity is largely unavailable. Urban areas are particularly dangerous for pedestrians as almost 80% of pedestrian fatalities nationally occurred in urban environments in 2014 (National Center for Statistics and Analysis 2016). Paradoxically, denser and more urbanized areas reduce injury severity and crash fatality risk as pedestrians are more numerous and vehicle speeds are lower (Clifton et al. 2009; Ewing and Dumbaugh 2009; Mohamed et al. 2013; Moudon et al. 2011). The ability to investigate national pedestrian injury trends by urban versus suburban or rural area may better facilitate local injury prevention planning. There is evidence that pedestrian injury morbidity and mortality varies between urban, suburban, and rural settings, and this variation may not be uniform across all areas and all age groups (Chakravarthy et al. 2007; Edwards et al. 2008; Ewing and Dumbaugh 2009; Kim et al. 2012). CDC's Web-based Injury Statistics Query and Reporting System recently added a feature to stratify by urbanicity, but this feature is only available for fatal injury data and for a limited number of years (National Center for Injury Prevention and Control 2017).

Baltimore City and the surrounding, independent Baltimore County, is the 13th most densely populated metropolitan area in the United States (U.S. Census Bureau n.d.). In 2014, almost half of all traffic fatalities in Baltimore occurred among pedestrians—the seventh highest rate compared to 35 other metropolitan areas with populations over 500,000 (National Center for Statistics and Analysis 2016). This is three times the national average, where 15% of traffic-related fatalities occur among pedestrians (National Center for Statistics and

Analysis 2016). A study of both fatal and non-fatal crashes in Baltimore found that 52% of pedestrians were culpable in the crash, compared with 36% of drivers (Preusser et al. 2002).

Furthermore, Baltimore City's (excluding Baltimore County) neighborhood walkability scores range from 17 to 98 on a scale of 0 to 100 (Baltimore Neighborhood Indicators Alliance 2016). A high walkability score signifies that daily errands can be easily performed on foot, while lower scores indicate a neighborhood's automobile dependence. The range of scores signifies a variety of urban landscapes across neighborhoods, as well as large discrepancies in availability of important amenities. Higher neighborhood walk scores are also correlated with higher volumes of pedestrians (Mooney et al. 2016). The increased burden of pedestrian injury, coupled with the diversity of urban terrains and differential access to essential resources across the city, underscores the importance of not relying on national trend data to understand the needs of an individual city's injury risk environment. Particularly in cities comparable to Baltimore, which does not have a comprehensive, up-to-date system in place to track, map, and disseminate information on pedestrian-involved crashes (City of Baltimore Department of Transportation 2015), analysis of local pedestrian injury trends may provide important information for safety planning not captured in national data, particularly data that is not stratified by urbanicity.

Because we hypothesize that Baltimore's local injury trends differ from national injury trends in significant and meaningful ways, the goal of this study is to describe the prevalence and distribution of pedestrian injury in Baltimore City. We investigate city-wide pedestrian injury trends to assess injury risk among nationally-identified risk groups, as well as identify risk groups and locations specific to Baltimore. We also investigate demographic risk factors for injury severity. Finally, we compare citywide trends to national trends to better understand Baltimore City's distinctive injury risk patterns.

METHODS

Data Sources

Pedestrian injury data were collected through emergency medical services (EMS) records from January 1 to December 31, 2014 (n=699) and were obtained from The Baltimore City Fire Department (BCFD) for Baltimore City, exclusive of Baltimore County. BCFD operates the City's EMS system, which deploys paramedics in response to all calls within the city limits (Knowlton et al. 2013). All of Baltimore City is served by a single EMS system, and these data are representative of all EMS calls for injured pedestrians within the city limits (BCFD does not service Baltimore County, which has its own, independent EMS service) (Cusimano et al. 2010). Paramedics on the scene confirmed the injury was caused by motor vehicle (Knowlton et al. 2013). Paramedics then recorded patient-level and other incident-related data on wireless tablet computers using proprietary software that was developed in compliance with the Electronic Maryland Ambulance Information System (Knowlton et al. 2013). Patient information included demographics; destination of transport; patient priority; and indicators of drug or alcohol use. Ambulances are routinely sent to precise locations of injured persons, allowing for the geographic mapping of injury events to better define high-risk locations (Cusimano et al. 2010; Ryb et al. 2007). EMS data also provide a measure of

when an injury occurred in addition to the geographic location, allowing for examination of temporal variation in injury risk (Cusimano et al. 2010).

National pedestrian injury data were obtained from the Centers for Disease Control and Prevention's (CDC) WISQARS Injury Statistics Query and Reporting System (National Center for Injury Prevention and Control 2017). For this analysis, we used both fatal and nonfatal injury data for 2014 because we did not know patient outcome after EMS transport. As almost 93% (n=646) of Baltimore injured pedestrians were transported to an emergency department (ED) for treatment, the WISQARS data provide a similar, nationally-representative population of injured pedestrians for comparison. We used 2014 Census population estimates for both national and Baltimore City population totals (U.S. Census Bureau n.d.). This research was approved by the Johns Hopkins Bloomberg School of Public Health Institutional Review Board.

Measures of Injury Risk Groups

The majority of patients were described by paramedics as Black, White or "Other Race," and there was scant representation of other minority groups, including Asians and Pacific Islanders. WISQARS race categories included White, Black, American Indian/Alaskan Native, Asian and Pacific Islander, and "other" (National Center for Injury Prevention and Control 2017). To facilitate comparisons across data sets, we grouped patients into three race categories: Black, White or Other Race.

We categorized patients into four-year age groups for all ages up to age 64. As few pedestrians age 65 and older were hit, we collapsed these four four-year age groups into one age category (65+) to avoid the possibility of these individuals being identifiable. We categorized time of day into one of eight three-hour time blocks; we collapsed these into four time-of-day categories (National Center for Statistics and Analysis 2016). We also categorized by day of the week and season (National Center for Statistics and Analysis 2016).

Because we do not know patient outcome after transport, we created a severity measure by recoding EMS patient priority into two severity levels (Marcin and Pollack 2002). While priority codes do not describe an injury in detail, they provide insight into acuteness (Marcin and Pollack 2002). Priority levels 1 and 2 were classified as the most severe injuries, Priority 3 and 4 as less severe (Maryland Institute for Emergency Medical Services Systems 2015). Patients who were dead at the scene (n=4) were classified to the most severe category.

Data Analysis

Locations of pedestrian injuries were geocoded and mapped using ArcGIS 10.4. This provided a visual representation of the distribution of pedestrian injury and allowed for visual comparison of this distribution against potential risk factors such as population density and income distributions. Population density was calculated by taking the total population of each Census block group and dividing by the area of the block group in square miles. Rate of pedestrian injuries by population was calculated by dividing the count of pedestrian injuries in a block group by the total population in that block group and multiplying by 1,000.

We used Pearson Chi-square Test of Independence to investigate differences in severity level across groups. We performed post hoc testing on statistically significant measures with more than two categories to determine which cells contributed most to a statistically significant omnibus test by comparing the significance levels of adjusted standardized residuals for each cell to Bonferroni-corrected p-values (Beasley and Schumacker 1995; García-pérez and Núñez-antón 2003).

Unadjusted pedestrian injury rates by age group, gender, and race for Baltimore were compared to national injury rates (fatal and non-fatal combined). We performed direct age, gender, and race adjustments for Baltimore rates to account for differences in city and national population distributions. We then calculated an incident rate ratio for each group by dividing the Baltimore adjusted rate by the national rate. Analyses were performed using SPSS 20.

Missing Data

Approximately 20% of patient race and almost 80% of patient drug and alcohol use was not recorded by paramedics. We could detect no significant differences in missing values for race by severity, age, or gender; therefore, we considered this variable as missing at random, eliminated the patients with missing data and only analyzed complete data for this variable (Karahalios et al. 2012). As the majority of drug and alcohol use indicators were missing, we decided not to evaluate this variable further.

RESULTS

A total of 699 pedestrians were involved in motor vehicle crashes in 2014—an average of two EMS transports each day (see Table A1 in the appendix). The mean age of injured pedestrians was 32.7 years (sd=18.6). The majority of injured pedestrians were men (n=435, 62.2%), and 73.2% were Black (n=421), where race was recorded (62.3% of the population of Baltimore City is Black).(U.S. Census Bureau n.d.) Race category was missing for 17.9% (n=124) of Baltimore and 23.2% (n=45,180) of national pedestrians. A quarter of injuries occurred from 3 p.m. to 5:59 p.m. (n=164), over 15% occurred on Friday (n=114), and almost a third occurred in the fall (n=205). The most frequently occurring day and time for injuries was Fridays from 3 to 5:59 p.m. (n=35, 5.0%). Drug and alcohol use indicators were recorded for only 23% (n=163) of patients; positive indicators of substance use were present in a quarter of patients (n=40) when it was noted at all.

The downtown neighborhood had the greatest number of injuries; the two adjoining block groups which make up downtown contained 36 and 13 injuries, respectively (Figure 1). The distribution of injuries throughout the city did not coincide with population density. Maps of the distribution of pedestrian injuries and population for Baltimore City are available in appendix Figure A1. In other words, there was not a consistent correlation between areas of concentrated population and areas of concentrated pedestrian injury.

Severe injuries occurred more frequently among men (p=0.008) (Table 1). Time of day was also a significant predictor of severity, with injuries occurring in the evening significantly more likely to result in a severe injury and injuries occurring in the morning significantly

less likely to result in a severe injury ($p<0.001$). Over 70% ($n=198$) of severely injured pedestrians were Black, but differences among racial groups were not statistically significant ($p=0.083$).

Twenty percent ($n=138$) of all injuries and 22% ($n=73$) of severe injuries occurred among children 14 and younger (Table 1). Half of all injuries ($n=69$) and half of severe injuries ($n=36$) occurred in the afternoon. Almost 72% of all injured children were Black ($n=99$), and almost 89% of severely injured children were Black ($n=55$); this difference was not significant.

Less than five percent ($n=32$) of all injuries occurred among adults 65 and older (Table A1), and older adults made up only 3.6% of severe injuries ($n=12$) (Table 1). Forty percent of all injuries ($n=13$) and half of severe injuries ($n=6$) in this age group occurred in the afternoon. Almost half ($n=15$) of all injuries and 46% ($n=5$) of severe injuries among older adults occurred among Blacks; this difference was not significant.

Baltimore's age-adjusted pedestrian injury rate is 1.13 per 1,000 population, almost twice the national rate of 0.61 per 1,000 ($IRR=1.82$, 95% $CI=(1.69, 1.96)$) (Table 2). Observed rates of pedestrian injuries for every demographic group were significantly greater than what would be expected if Baltimore's injury rates were comparable to national rates. This difference was particularly pronounced among children 14, where the age-adjusted rate of 1.30 per 1,000 was almost five times greater than the national average of 0.27 per 1,000 ($IRR=4.81$, 95% $CI=(4.05, 5.71)$). The sex-adjusted rate of 1.14 per 1,000 population was also substantially greater than the national average of 0.45 per 1,000—a difference in magnitude of 2.5 times ($IRR=2.53$, 95% $CI=(2.34, 2.73)$).

DISCUSSION

This study provides a description of pedestrian injury localized to one metropolitan area and identifies unique demographic and geographic risk groups; it also demonstrates how national studies may lack specificity when used to evaluate local injury trends. Comparing Baltimore to national trends revealed several differences, both in risk groups and locations. The downtown neighborhood—the most walkable Baltimore neighborhood with a Walk Score of 98 (Baltimore Neighborhood Indicators Alliance 2016)—reported the highest number of pedestrian injuries. This is unsurprising as the convergence of people and vehicles at popular destinations such as workplaces, restaurants, bars, and recreation and entertainment venues may provide more opportunities for pedestrians and vehicles to interact, increasing crash risk (Dai et al. 2010). However, the distribution of injuries throughout the city did not coincide with population distribution, suggesting that neighborhood risk for pedestrian injury was not solely related to population density. A possible explanation for this finding could be related to traffic safety infrastructure located in densely-populated urban areas. A review of empirical studies on traffic safety infrastructure found that street design in densely-populated urban areas was associated with decreased pedestrian injury risk and injury severity (Ewing and Dumbaugh 2009). Further inquiry into the local streetscape and other possible pedestrian injury risk factors is needed to understand why the downtown region experiences a high number of pedestrian injuries.

Despite similar population distributions for children age 14 and younger, the Baltimore child injury rate is five times the national average. Road crossing is a complex behavior, and preadolescent children lack the cognitive ability to make well-planned crossing decisions, resulting in higher injury rates among children (Retting et al. 2003; Stavrinou et al. 2009). In urban areas, walking may be a more common mode of transportation for children, especially in families that do not own cars (Durkin et al. 1999). Thirty percent of Baltimore households on average did not have access to a car for personal use in 2014; in some neighborhoods this percentage was as high as 72% (Baltimore Neighborhood Indicators Alliance 2016). Black children are more likely to live farther distances from school than White children, which could account for increased injury rates among children and which may explain why almost three-quarters of injured children were Black (Cottrill and Thakuriah 2010; Steinbach et al. 2010). Children's behavior, such as emerging from between parked cars, playing in the street, and "dart and dash" crossing, may add to increased crash rates (DiMaggio and Durkin 2002), although those data were not available in this study. Furthermore, a majority of Baltimore injuries occur in the afternoon directly after school dismissal, in contrast to national injury patterns where injuries are more likely to occur after dark (National Center for Statistics and Analysis 2016). Half of all injuries among young children in Baltimore occurred in the afternoon, similar to a New York City study of pediatric pedestrian injury (DiMaggio and Durkin 2002).

The overrepresentation of Blacks among injured pedestrians in general, and children in particular, was not attributable to population distribution alone—namely, that African Americans make up a higher percentage of Baltimore's population compared to the national average—as the race-adjusted injury rate was almost twice the national average. Our findings are comparable to previous studies which observed that minority groups were at higher risk for pedestrian injury (Laflamme and Diderichsen 2000; Loukaitou-Sideris et al. 2007; Ryb et al. 2007) and fatality (Beck et al. 2007; Campos-Outcalt et al. 2002) compared to their White counterparts. It is possible that Blacks in Baltimore are more likely to walk or take public transportation than other groups, resulting in greater exposure to street danger and increased injury risk (Cottrill and Thakuriah 2010; Loukaitou-Sideris et al. 2007). To date, conclusive evidence explaining minority children's higher pedestrian injury rates has yet to be determined (Steinbach et al. 2010, 2016).

While the age-adjusted rate of injuries for older adults was elevated compared to the national rate, older adults did not make up a substantial portion of injured pedestrians. Adults age 65 and older made up less than 5% of injured pedestrians—less than the national average of 11% for all injured pedestrians (National Center for Statistics and Analysis 2016). Older adults also made up a small proportion of severe injuries. Less than 4% of severe injuries occurred in this age group in Baltimore, while 38% of pedestrian deaths in New York City occurred among older adults (Nica et al. 2006). This discrepancy is surprising as seniors make up a similar percent of the total population of each city (U.S. Census Bureau n.d.). Older adults in Baltimore may be less mobile and have fewer opportunities to come into contact with traffic. They may also be more vigilant: A Maryland study found that older, urban-dwelling adults considered themselves at increased risk for pedestrian injury and were more observant of traffic safety procedures than their suburban counterparts (Reed and Sen 2005).

Limitations

This study is cross-sectional and, therefore, does not allow for discussion of changes in the injury risk environment over time. Because we could not link EMS data with hospital data, we were unable to track what happened to the pedestrian after transport; consequently, this study does not discuss pedestrian fatality in particular but pedestrian injury in general. We also did not have access to a description of the circumstances surrounding each injury, limiting our ability to draw conclusions about injury mechanisms or make recommendations for targeted injury prevention strategies. However, previous studies have shown that the majority of pedestrians are struck within a mile of their home (Anderson et al. 2012; Haas et al. 2015), suggesting that injured pedestrians are representative of the neighborhoods in which they are struck. Consequently, this research may still provide guidance for pedestrian injury prevention targeted to specific neighborhoods.

Race category was missing from approximately one-fifth of the Baltimore and national populations. It is possible that these pedestrians were different from their counterparts in meaningful or systematic ways, biasing our conclusions regarding injury rates for racial groups. Previous studies using police accident reports have shown pedestrian injuries among Blacks are often underreported in police data sets (Sciortino et al. 2005). Paramedics are not required to alert police when they treat a person struck by a motor vehicle; some pedestrians may be reluctant to summon police and file a report when the police are not initially present at the scene of a crash (Sciortino et al. 2005). It is possible that EMS records could be more complete for injuries which occur among certain minority groups, even with missing data.

As similar data comparable to the Baltimore City EMS data were not publicly available for other metro areas, we were only able to compare Baltimore's pedestrian injury rates to national data. It is possible that comparing Baltimore to other, similar cities—particularly cities experiencing similar patterns of development and gentrification—would provide further insight into local pedestrian injury trends and strategies for preventing future injuries. For example, there are 25 new residential development projects underway in Baltimore's downtown district alone—the neighborhood with the highest pedestrian injury count (Papagani 2016). Future studies should compare Baltimore's pedestrian injury rates with those of other, similar cities to inform targeted pedestrian injury prevention strategies.

While national trends in pedestrian injury are useful for focusing research questions and identifying risk groups for directed inquiry, they may lack specificity when characterizing risk groups and risk factors for individual metropolitan areas. To better facilitate local injury prevention planning, national pedestrian injury research should allow for stratification by urbanicity as injury rates and associated risk factors may vary in urban versus rural or suburban settings. A deeper understanding of the complex mechanisms which give rise to unique local and regional risk patterns is necessary to effectively prevent future pedestrian injuries.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Rate of pedestrian injuries per 1,000 population by Census block group for Baltimore City, 2014

Data Sources: Baltimore City Fire Department; 2014 U.S. Census estimates

Table 1

Characteristics of pedestrian injuries stratified by injury severity (n=699)

Characteristic	Severity Level		p-value
	Life Threatening or Dead n (%)	Less Severe n (%)	
Age groups			0.689
0–4	12 (3.6)	8 (2.2)	
5–9	27 (8.2)	24 (6.5)	
10–14	34 (10.3)	33 (8.9)	
15–19	26 (7.9)	39 (10.6)	
20–24	33 (10.0)	45 (12.2)	
25–29	34 (10.3)	38 (10.3)	
30–34	26 (7.9)	30 (8.1)	
35–39	16 (4.9)	18 (4.9)	
40–44	22 (6.7)	27 (7.3)	
45–49	21 (6.4)	22 (6.0)	
50–54	38 (11.6)	27 (7.3)	
55–59	15 (4.6)	22 (6.0)	
60–64	13 (4.0)	16 (4.3)	
65+	12 (3.6)	20 (5.4)	
Age 14 (ref: Age 15)	73 (22.2)	65 (17.6)	0.130
Age 65 (ref: Age 64)	12 (3.6)	20 (5.4)	0.264
Race (n=574)			0.083
Black	198 (71.5)	222 (74.7)	
White	58 (20.9)	65 (21.9)	
Other Race	21 (3.7)	10 (3.4)	
Sex			0.008
Male	222 (67.5)	213 (57.7)	
Female	107 (32.5)	156 (42.3)	
Day of week			0.289
Monday	46 (14.0)	63 (17.1)	
Tuesday	50 (15.2)	48 (13.0)	
Wednesday	58 (17.6)	48 (13.0)	
Thursday	48 (14.6)	62 (16.8)	
Friday	58 (17.6)	55 (14.9)	
Saturday	42 (12.8)	51 (13.8)	
Sunday	27 (8.2)	42 (11.4)	
Time of Day *			<0.001
Late Night	25 (7.6)	21 (5.7)	

Characteristic	Severity Level		p-value
	Life Threatening or Dead n (%)	Less Severe n (%)	
Morning	53 (16.1) [‡]	110 (29.8) [‡]	
Afternoon	128 (38.9)	142 (38.5)	
Evening	123 (37.4) [‡]	96 (26.0) [‡]	
Season ^{**}			0.098
Winter	58 (17.6)	88 (23.8)	
Spring	86 (26.1)	96 (26.0)	
Summer	89 (27.1)	76 (20.6)	
Fall	96 (29.2)	109 (29.5)	

* Late night consisted of the hours from 12 a.m. to 5:59 a.m.; Morning from 6 a.m. to 11:59 a.m.; Afternoon from noon to 5:59 p.m.; Evening from 6 p.m. to 11:59 p.m.

** Winter included the months of January, February, and December; Spring from March to May; Summer from June to August; and Fall from September to November

[‡] Statistically significant compared to Bonferroni-corrected p-value

Table 2

Unadjusted and adjusted rates of pedestrian injuries in Baltimore and the United States for 2014

Characteristic	Baltimore		National*	Magnitude of difference between adjusted and national rates IRR (95% CI)
	Unadjusted Rate (per 1,000)	Adjusted Rate** (per 1,000)	Rate (per 1,000)	
All Age Groups	1.13	1.11	0.61	1.82 (1.69, 1.96)
Age 0–14	3.89	1.30	0.27	4.81 (4.05, 5.71)
Age 15–29	3.83	1.37	0.71	1.93 (1.77, 2.11)
Age 65+	0.44	0.46	0.31	1.48 (1.04, 2.11)
Race***	0.94	0.80	0.47	1.70 (1.56, 1.85)
Sex	1.13	1.14	0.45	2.53 (2.34, 2.73)

* Data combines both fatal and non-fatal injuries. Obtained from Centers for Disease Control and Prevention, National Center for Injury Prevention and Control, <http://www.cdc.gov/injury/wisqars/>

** Direct adjustment using population distribution of indicated demographic group from 2014 U.S. Census

*** Race not recorded in 124 of Baltimore City injury cases and 45,180 of national injury cases