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An Analysis of Distance from Collision Site to Pedestrian Residence in Pedestrian versus Automobile Collisions Presenting to a Level 1 Trauma Center

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ABSTRACT – This study tests the hypothesis that most pedestrian collisions occur near victims' homes. Patients involved in automobile versus pedestrian collisions who presented to the emergency department at a Level I trauma center between January 2000 and December 2009 were included in the study. Patient demographics were obtained from the trauma registry. Home address was determined from hospital records, collision site was determined from the paramedic run sheet, and the shortest walking distance between the collision site and pedestrian residence was determined using Google Maps. We summarized distances for groups with the median and compared groups using the Kruskal-Wallis rank test. We identified 1917 pedestrian injury cases and identified both residence address and collision location for 1213 cases (63%). Forty-eight percent of the collisions were near home (within 1.1 km, 95% CI 45-51%). Median distance from residence to collision site was 1.4 km (interquartile range 0.3-7.4 km). For ages 0-17, the median distance 0.7 km, and 59% (95% CI 54-63%) of collisions occurred near home. For ages 65 and older, the median distance was 0.6 km and 65% (95% CI 55-73%) were injured near home. Distance did not differ by sex, race, ethnicity, or blood alcohol level. More severe injuries (Injury Severity Score ≥ 16) occurred further from home than less severe injuries (median 1.9 km vs. 1.3 km, p=.01). Patients with a hospital stay of 3 days or less were injured closer to home (median 1.3 km) than patients with a hospital stay of 4 days or more (median 1.8 km, p=.001). Twenty-two percent were injured within the same census tract as their home, 22% on the boundary of their home census tract, and 55% in a different census tract.

INTRODUCTION

Pedestrian injuries continue to be a significant burden of disease throughout the world [Naci, Chisholm, Baker, 2009]. Each year, over 1.2 million people are killed and as many as 50 million others are injured on the world's roads [World Health Organization, 2009]. In 2009, in the United States alone, 4,092 pedestrians were killed and more than 59,000 others were injured in automobile-pedestrian collisions [National Highway Traffic Safety Administration, 2009]. Many victims spend long periods in the hospital and are unable to live or work as they did prior to the collision [Peng, Bongard, 1999]. The resulting economic burden includes direct healthcare costs as well as indirect costs of forfeited earnings, decreased productivity, and years of potential life lost.

Literature exploring child pedestrian injury suggests that collisions often occur close to children's homes or schools [Agran, Winn, Anderson, 1994; Malek, Guyer, Lescoheir, 1990; Braddock, Lapidus, Cromley, 1994; Roberts et al, 1997; Lightstone, Dhillon, Peek-Asa, 2001; La Scala, Guenewald, Johnson, 2004]. Additionally, past studies have identified factors associated with the risk of adult pedestrian collision and injury such as age and gender [La Scala, Gerber, Gruenewald, 2000; Graham, Glaister, Anderson, 2005; Hijar, Kraus, Tovar, 2001; Gorrie, Brown, Waite, 2008], alcohol involvement [La Scala et al, 2000; Shuurman, Cinnamon, Crooks, 2009; Paulozzi, 2006], and socio-economic status [Rivara and Barber, 1985; La Scala et al, 2000; Graham et al, 2005; Chakravarthy, Anderson, Ludlow, 2010] among others. Despite the large body of literature regarding auto-pedestrian collisions, there continues to be a paucity of studies examining proximity to home of adult pedestrian-auto collisions. Two older studies done in 1949 and 1961 found that most injuries occurred near the pedestrians' home residence [Chandler, 1949; Haddon, Valien, McCarroll, 1961]. No recent studies have examined proximity to home for injured pedestrians of all ages.

Pedestrian injury can result from pedestrian activity near home without a specific destination, from a trip that is entirely on foot, and from walking or crossing a street after a trip by another mode of transportation. In the 2009 National Household Travel Survey (NHTS), the mean length of walking trips was 0.7 miles (1.1 km) and the mean length of all trips was 9.75 miles (16 km) [Federal Highway Administration, 2009].

The current study aims to test the hypothesis that most pedestrian collisions occur near victims' homes. Individuals presenting to a Level I Trauma Center over a 10-year period as pedestrian trauma victims involved in auto versus pedestrian collisions are analyzed. We also examined the relationship of distance from home to demographic characteristics (age, gender, race and ethnicity), blood alcohol level, and measures of injury severity (injury severity score) and resource usage (hospital length of stay). Basic demographic characteristics may be related to the mode of travel and the choice of destination. Alcohol-related pedestrian injuries are associated with the density of bars [La Scala et al, 2000] and may be further from home. The severity of injury is related to vehicle speed [Rosén, Stigson, Sander, 2011] and thus may occur at locations outside of residential neighborhoods.

METHODS

We conducted a retrospective, observational study at the University of California, Irvine Medical Center (UCIMC), an urban California Level I trauma center. Data was collected from the UCIMC Trauma Registry, a centralized database that collects relevant patient and injury details for each trauma that presents to the UCIMC emergency department.

Setting:

UCIMC is one of three trauma centers in Orange County. It is the only Level I trauma center, and provides care for nearly half of the county's trauma cases. Orange County has population of 3,010,000 in 2010 [US Census Bureau, 2011a]. The median household income is $74,000 and 10% of the population lives in households with income below the federal poverty level [US Census Bureau, 2011b]. Although the county is generally affluent, it includes older, denser cities with poverty levels as high as 18% [US Census Bureau, 2011b].

Study Participants

All patients involved in automobile versus pedestrian collisions who presented to the UCIMC emergency department between January 2000 and December 2009 were included. Recorded details in the standard trauma documentation included patient medical record number, age, gender, race, blood alcohol level (BAL) upon presentation, hospital length of stay (LOS), and final outcome. The injury severity score (ISS) [Baker et al., 1974] was calculated according to the established trauma protocol.

Patient demographics were obtained from the trauma registry. Home address was determined from hospital records, and collision site was determined from the paramedic run sheet. The trauma data includes no other information about the trip.

Distance Measurement

The shortest walking distance between the collision site and pedestrian home residence was determined using Google Maps (Google, Inc., Mountain View, CA) for patients whose home address was located in southern California, defined as the five-county region made up by Orange and neighboring counties: Los Angeles County, San Bernardino County, Riverside County, and San Diego County. Collisions with the same address as the pedestrian's residence were assigned a distance of 0.01 km, a distance that is less than the precision of the street address location. Collisions involving pedestrians with home addresses outside of southern California were assigned a distance of 160 km. Because we report medians and percentiles, these extreme values did not influence the results presented. We defined close to home as within 1.1 km, the mean length of a walking trip in the 2009 NHTS.

The following addresses were considered to be missing: incomplete collision site from the Trauma Registry database, incomplete home address from the medical record, addresses that underwent significant auto-correction by Google Maps (changes exceeding 2 letters of street name, zip code, or city non-adjacent to original address), residence address for homeless pedestrians, and home address or collision site given as the street address of a local medical facility (assumed to be inter-facility transfers).

Pedestrian residences and collision sites were assigned a census tract from the 2000 US decennial census using the address search function of American FactFinder (US Census Bureau, Washington, DC. url: http://factfinder.census.gov/servlet /AGSGeoAddressServlet). Collision sites on streets that form census tract boundaries were assigned to both census tracts. Thus collisions site at intersections could be assigned up to four census tracts. Residence and collisions site census traces were compared and divided into three categories: collisions that occurred within the residence census tract, collisions on the boundary of the residence census tract, and collisions that occurred in a different census tract from the residence.

Statistical Analysis

Distances and census tracts were entered in Microsoft Excel. The data were analyzed using Stata (version 10.1, StataCorp, College Station, TX). We summarized distances for groups within the 25th percentile, median (50th percentile), and 75th percentile. We compared groups using the Kruskal-Wallis analysis of variance by ranks. We also report the percentage near home (within 1.1 km) with 95% exact binomial confidence intervals (CI).

RESULTS

We identified 1917 cases by the mechanism of injury recorded in the hospital trauma registry. A home address was identified for 1482 pedestrians (77%), and a collision site was identified for 1532 (80%). Both residence address and collision location were identified for 1213 cases (63%). The distribution of distances from residence to collision site is shown in Table 1. The median distance was 1.4 km (interquartile range [IQR] 0.3-7.4 km). Forty-eight percent of the collisions were within 1.1 km of home (95% CI 45-51%).

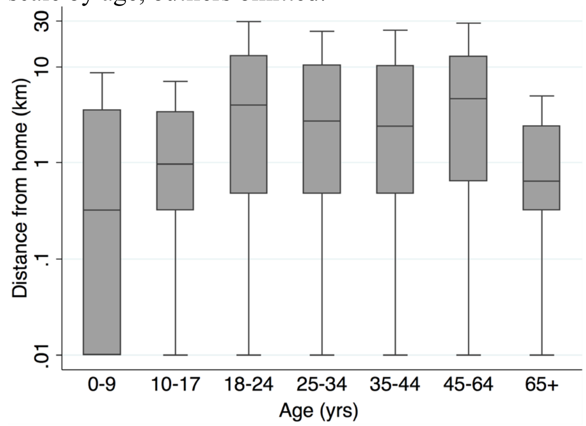
Table 1. Distance from residence to collision site (n=1213).

Distance	Number	Percent
<0.1 km	209	17.2
0.1-0.99 km	343	28.3
1.0-9.9 km	414	34.1
10-99 km	203	16.8
≥100 km	44	3.6

Median distance was less for ages 0-17 (0.7 km) and for ages 65 and older (0.6 km) than for ages 18-64 (3.4 km, p=.0001). For age 0-17 years, 59% (95% CI 54-63%) of collisions occurred near home (within 1.1 km). For age 18-64 years 37% (95% CI 33-40%) and for age 65 and older 65% (95% CI 55-73%) were injured near home.

A more detailed breakdown of age is shown in Figure 1. Distance from home to collision site in km is shown on a log scale. The shaded boxes indicate the IQR, which extends from the 25th percentile to the 75th percentile. The median is shown by a white line. The whiskers indicate the most extreme values that are within 1.5 IQR of the boxes. Because of the large number of observations, the more extreme outliers are not shown.

Figure 1. Box plot of distance from home on a log scale by age, outliers omitted.



Distance did not differ by sex, race, ethnicity, or BAL (Table 2). BAL is shown only for adults, as it was not routinely measured in children. More severe injuries, defined as ISS ≥ 16, occurred farther from home than less severe injuries. Patients with LOS ≤ 3 days were injured closer to home than patients with a hospital stay of 4 days or more. A more detailed breakdown of LOS is shown in Figure 2.

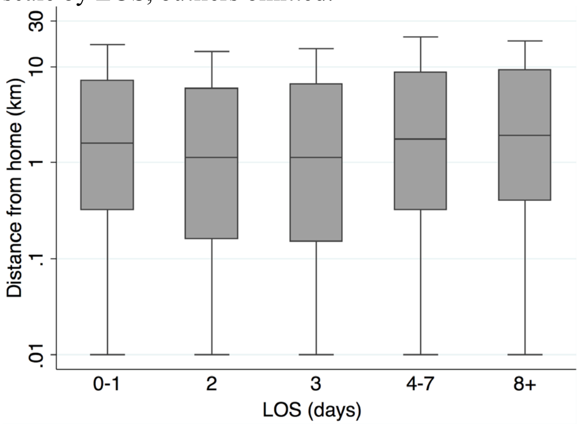
Table 2. Percentiles of distance from home to crash site (km) by selected characteristics, n=1213 except as noted.

		Percentiles:			
	n	25th	50th	75th	p
Males	766	0.3	1.3	6.8	.42
Females	447	0.3	1.6	8.7	
Non-Latino					
White	684	0.3	1.4	8.3	.99
Latino	181	0.1	2.1	7.7	
Asian	150	0.5	1.2	6.4	
Other	198	0.3	1.6	6.1	
BAL+*	269	0.5	2.4	10.0	.61
BAL-	484	0.3	2.4	9.8	
ISS 0-15**	918	0.3	1.3	6.9	.01
ISS 16+	282	0.5	1.9	9.0	
LOS 0-3	702	0.2	1.3	6.6	.001
LOS 4+	511	0.3	1.8	8.9	

*Restricted to 771 pedestrians age 18 years and older, 36 with missing BAL.
**ISS was missing for 13 pedestrians.

Twenty-two percent of the pedestrians were injured within the same census tract as their residence, 22% on a street or intersection that formed part of the border of that same census tract, and 55% in a

Figure 2. Box plot of distance from home on a log scale by LOS, outliers omitted.



different census tract. Children and youth age 17 and younger had the highest proportion of collisions occurring with the census tract of their residence (Table 3, p<.00001).

Table 3. Number (percent) of collision sites relative to residence census tract, by age group.

	Pedestrian age (years)			
Collision site relative to residence census tract	0-17	18-64	65+	Total
Within	163 (37)	79 (12)	28 (21)	270 (22)
On the boundary	89 (20)	132 (21)	51 (38)	272 (22)
Different census tract	190 (43)	427 (67)	54 (41)	671 (55)
Total	442	638	133	1213

DISCUSSION

In our study population, 48% of pedestrians were injured near home. The majority of collision involving pedestrian age 17 and younger and 65 and older occurred near home. There is extensive pediatric literature addressing the proximity of child auto-pedestrian collisions to victims' homes or schools [Agran et al, 1994; Malek et al, 1990; Braddock et al, 1994; Roberts et al, 1997; Lightstone et al, 2001; La Scala et al, 2004].

Only two prior studies have examined distance from pedestrian-auto collision site to pedestrian home residence in a wider and more comprehensive adult population. Chandler (1948) used police traffic file data and calculated the shortest walking route between the site of auto-pedestrian collision and the pedestrian residence. An inverse proportionality was found between collision frequency and distance from home. Chandler concluded that the results reflect that most pedestrians do a majority of their walking close to home. Haddon et al (1961) conducted a case-control study using police Accident Investigation Squad data of all fatal pedestrian-auto collisions that occurred during a 6-month period in Manhattan, NY. The median distance from pedestrian residence to collision site was 1000-1499 feet (0.3-0.5 km).

Pedestrian injuries occurring near home are consistent with pedestrian activity near home and with trips that are entirely on foot. These injuries may be a function of neighborhood destinations and the neighborhood traffic environment. Pedestrian injuries occurring further from home are consistent with injuries occurring after a trip by another mode of transportation. These injuries may be related to the traffic environment at the collision location but not to population characteristics of that neighborhood.

Our study found that 22% of collisions occurred within the same census tract in which the victim lived and another 22% on the boundary of the home census tract, while 55% of collisions occurred in different census tracts (Table 3). Census tract characteristics have been used to approximate the demographic characteristics of pedestrians and the environment of pedestrian collisions. However, many collisions that injure pedestrians occur in different census tracts or along the borders of census tracts. As these borders are frequently arterial streets, they may have important environmental differences from the interior of census tracts.

The study confirms previous findings in a larger population, over a 10-year period using a Trauma Registry inclusive of all pedestrian-auto traumas who presented to Level I Trauma Center in an academic hospital. The current study used data from a period of 10 years. Furthermore, this study analyzed collisions in a larger geographic area.

Important additional findings to note include associations between distance and age, ISS, and LOS (Table 2). The extremes of age, i.e. the relatively young (≤ 17 years) and the relatively old (≥ 65 years) were hit closer to home, while adults age 18-64 years were hit farther from home (Figure 1). This could possibly be explained by more time spent walking or playing close to home by the young and old who cannot drive or no longer drive. Both may not have the logistical means to be further from home and spend more time close to home, thus having a greater probability of being struck close to home. Adults age

18-64 years are more independent, make more trips, and travel farther than other age groups [Santos et al, 2011].

Our study also showed that those victims with a higher ISS and with longer LOS were hit farther from home (Table 2). This is consistent with low-speed collisions on residential streets close to home, and more severe collisions further from home. In an increasingly cost and resource conscious health care environment and with increasing pressures to decrease hospital LOS, exploring ways to prevent severe injuries from any trauma, especially highly avoidable auto-pedestrian traumas, becomes paramount.

These data were collected at one trauma center. We believe that they are a function of travel patterns and exposure to traffic, and some difference might be found in other communities. However, several other investigators have found that children experience pedestrian injuries close to home, and we expect that similar results would be found for children in many communities.

Implications

Ecologic studies of adult pedestrian injuries, which use census data as a source of both denominators and population characteristics are likely to underestimate associations because pedestrians injured far from home may not share the characteristics of the population living near the site of the collision. On the other hand ecologic studies of child pedestrian injuries, such as those of Rivara and Barber [1985], La Scala et al [2000] and Chakravarthy, Anderson, and Ludlow [2012] may identify important risk factors because the injured pedestrians and the population exposed to traffic are more similar to the population residing near the collision site. The finding of Graham et al [2005] that local area socioeconomic deprivation was more strongly related to child than adult pedestrian injuries may be due to the occurrence of child pedestrian injuries closer to home.

Limitations

There are several limitations to the study. Our study excluded 704 pedestrians secondary to unavailable data. The missing data included home addresses or collision sites. This made our primary outcome, the distance between collision site and pedestrian residence, impossible to calculate. Other missing data points included demographic information, blood alcohol levels, or other data. In addition, the current study examines only those individuals who were injured severely enough to warrant or seek treatment at a Level I Trauma Center or who actively chose to walk into the aforementioned Emergency Department after injury. Individuals who presented or were subsequently treated at other institutions such as Level II or III Trauma Centers and community hospitals, urgent care centers, or their primary care providers are clearly missed in this study design. Lastly, our study does not include individuals who were involved in auto-pedestrian collisions but never sought medical care. Police and public record data could be combined with trauma registry data in the future for a more inclusive study.

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CONCLUSION

In this sample of pedestrians treated at a Level 1 Trauma Center, the median distance from residence to collision site was 1.4 km. Only 48% of the collisions were hear home (within 1.1 km, 95% CI 45-51%). However, the majority of collision involving pedestrian age 17 and younger and 65 and older occurred near home (within 1.1 km). Pedestrians with more severe injuries and longer LOS were injured further from home than pedestrians with less severe injuries and shorter LOS. Most collisions occurred in a different census tract from the pedestrian's residence. Although the majority of injuries to children, youth, and older adults occur near home, differences between home and collision environments may complicate the interpretation of routinely collected pedestrian collision data, especially for adults 18-64 years.

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