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Urban crash-related child pedestrian injury incidence and characteristics associated with injury severity

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ABSTRACT

Objective: Describe age-based urban pedestrian versus auto crash characteristics and identify crash characteristics associated with injury severity.
Materials and methods: Secondary analysis of the 2004–2010 National Highway and Traffic Safety Administration database for Illinois. All persons in Chicago crashes with age data who were listed as pedestrians ($n = 7175$ child age $\leq$19 yo, $n = 16,398$ adult age $\geq$20 yo) were included. Incidence and crash characteristics were analyzed by age groups and year. Main outcome measures were incidence, crash setting, and injury severity. Multivariate logistic regression analysis was performed to estimate injury severity by crash characteristics.
Results: Overall incidence was higher for child (146.6 per 100,000) versus adult (117.3 per 100,000) pedestrians but case fatality rate was lower (0.7% for children, 1.7% for adults). Child but not adult pedestrian injury incidence declined over time (trend test $p < 0.0001$ for <5 yo, 5–9 yo, and 10–14 yo; $p < 0.05$ for 15–19 yo, $p = 0.96$ for $\geq$20 yo). Most crashes for both children and adults took place during optimal driving conditions. Injuries were more frequent during warmer months for younger age groups compared to older (χ^2 $p < 0.001$). Midblock crashes increased as age decreased ($p < 0.0001$ for trend). Most crashes occurred at sites with sub-optimal traffic controls but varied by age ($p < 0.0001$ for trend). Crashes were more likely to be during daylight on dry roads in clear weather conditions for younger age groups compared to older (χ^2 $p < 0.001$). Daylight was associated with less severe injury (child OR 0.93, 95% CI 0.87–0.98; adult OR 0.90, 95% CI 0.87–0.93).
Conclusion: The incidence of urban pedestrian crashes declined over time for child subgroups but not for adults. The setting of pedestrian crashes in Chicago today varies by age but is similar to that seen in other urban locales previously. Injuries for all age groups tend to be less severe during daylight conditions. Age-based prevention efforts may prove beneficial.

1. Introduction

1.1. Current pedestrian crash injury knowledge

Each year in the United States (US), approximately 900 child pedestrians (<19 years old (yo)) are killed with an additional 51,000 injured and 5300 hospitalized secondary to injuries (Committee on Injury, Violence, and Poison Prevention, 2009). This accounts for 45,000 days of hospitalizations and >$290 million in inpatient charges (Conner et al., 2010). Children follow a unique developmental pattern prior to reaching adulthood which puts them at risk for different pedestrian behaviors and crash characteristics. For example, a toddler may not realize the consequences of dashing between parked cars into the road to follow a runaway ball whereas an adult may have the ability to follow pedestrian signals but choose not to for one reason or another. The resulting crash characteristics likely vary. Studies suggest that pedestrian injuries follow age-based trends that also vary by gender, location, environmental, and social factors. An

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analysis of New York data suggested the incidence of child pedestrian injuries to be 246 per 100,000 with a case fatality rate of 0.6% but that these crashes are becoming less frequent. Further, the analysis found younger children were more likely to be hit midblock during daylight and an increase during summer months but that road and weather conditions had no significant affect (DiMaggio and Durkin, 2002). Other studies suggest increased injury rates in males, less fatal injury in children, increased severity in mid-block crashes, and that about 18% of all pedestrian crashes are hit-and-run (Centers for Disease Control and Prevention Morbidity and Mortality Weekly Report, 2013; Stimpson et al., 2013; Slaughter et al., 2014; MacLeod et al., 2012; Rothman et al., 2012). However, as suggested by Ulfarsson et al., there is much variability in the literature making it unclear if these findings are generalizable to other geographic locations for use in targeted injury prevention initiatives (Ulfarsson et al., 2010).

1.2. Influence of traffic technology changes, personal electronic device use, and regulations

Large strides have been made in traffic technologies such as countdown signals, road design, and in-vehicle technology (e.g. rear cameras, backup sensors, pedestrian detection systems, blind spot information systems, predictive forward collision warning systems). These have likely decreased child pedestrian versus auto events. While data are conflicting about the utility of pedestrian countdown signals as an injury prevention strategy, in 2006 Chicago regulated that all new pedestrian signals and all those needing repair be done with countdown signals (Camden et al., 2012; Markowitz et al., 2006; Federal Highway Administration, 2008; Richmond et al., 2013).

Personal electronic device utilization is also likely modifying both driver and pedestrian behaviors. Cellphone use is steadily increasing with approximately 88% of adults and 77% of children 12–17 yo owning cellphones in 2011 (up from 75% in 2009 and 45% in 2004) (Lenhart, 2012; Smith, 2012). Studies suggest that child pedestrian safety is compromised when children use cellphones or headphones; similar findings have been shown in college age and adult pedestrians (Stavrinos et al., 2009, 2011; Chaddock et al., 2012; Schwebel et al., 2012; Nasar et al., 2008; Lichenstein et al., 2012). Increases in adult cellphone use over time have led to more distractions for drivers as well with 5% of drivers using hand held devices while driving in 2010 (Thompson et al., 2012; Young et al., 2012; Neyens and Boyle, 2007; Smith, 2010; National Highway Traffic Safety Administration, 2012). The data show that both hand held and hands free cellphone use while driving negatively impact driver performance (Ishigami and Klein, 2009; Klauer et al., 2013; Caird et al., 2008; Wilson and Stimpson, 2010). Furthermore, studies show that while pedestrian crash incidence is declining, pedestrian deaths from distracted driving are on the rise (Stimpson et al., 2013).

Several laws were implemented in Chicago and state-wide to minimize distracted driving risks to pedestrians (see Appendix A online for timeline of interventions). The most notable of these regulations included the 2005 Chicago ban on handheld cellphone devices while driving, the 2008 Chicago texting while driving ban, and the 2010 Illinois state-wide texting while driving ban.[1,2,3] However, studies have shown varying efficacy of similar policies in other locals (McCartt et al., 2014; Lim and Chi, 2013).

1.3. Goals and hypothesis

Our study is designed to provide an age-based description of current pedestrian injury incidence, trends, and crash characteristics of urban child (≤19 yo) and adult (≥20 yo) pedestrian versus auto events in the setting of these multifactorial changes. The aim is to better understand current age-based trends in urban child pedestrian injury characteristics compared to their adult counterparts in order to inform prevention and education practices. We hypothesize that traffic technology changes, personal electronic device use, and regulations are altering pedestrian crash incidence, trends, and characteristics.

2. Materials and methods

2.1. Data sources and inclusion criteria

A descriptive, population based study was conducted on child (≤19 yo) and adult pedestrian crashes in Chicago from 2004 to 2010. These years were chosen to coincide with Chicago injury prevention initiatives and to include the most recent data available. Data were obtained from National Highway and Traffic Safety Administration (NHTSA) statewide data extract files. These data are based on the Illinois Traffic Crash Report SR 1050 (ITCR) forms, are maintained by NHTSA, and are in the public domain. The ITCR form is completed by a law enforcement officer for each reported crash and is the only crash report form approved by Illinois law. The NHTSA database, rather than the Fatality Analysis Reporting System (FARS) or the National Vital Statistics System, was selected because it provides the most inclusive pedestrian injury data and is less likely to underestimate the true number of injuries since all reported crashes regardless of severity are included.

Data are provided from NHTSA as anonymous data in three separate files for each year – a crash file, a person file, and a vehicle file. All information was coded by NHTSA. The original database for the state of Illinois from 2004 to 2010 included 2,676,621 crashes and 6,246,277 people; 41,640 pedestrians were involved in crashes. A case was considered to be any child (≤19 yo) or adult (≥20 yo) pedestrian involved in a crash that took place in Chicago for which a crash report was completed and pedestrian age provided. See Appendix B for age breakdown of included cases. There were 1549 of 25,122 cases (6%) that were excluded due to lack of age data. When compared to cases where age was known, cases where age was unknown had less severe injuries (0.1% versus 1.4% fatal, $p < 0.001$), more males (57% versus 53%, $p < 0.05$), increased midblock crashes (57% versus 49%, $p < 0.001$), more crashes at uncontrolled sites (59% versus 53%, $p < 0.001$), and fewer hit-and-run crashes (26.3% versus 33.5%, $p < 0.001$) but no differences in light, road, weather, or month category. Some crashes involved more than one pedestrian in which case all pedestrians with age data were included in the analysis as individual cases.

For driver analysis, drivers in pedestrian crashes involving more than one driver were excluded from analysis ($n = 913$ cases total, 317 in child pedestrian crashes, 596 in adult pedestrian crashes). For each crash involving a single driver hitting multiple pedestrians, the driver was only included once for each crash involving child pedestrians and once for each crash involving adult pedestrians (see Appendix C).

Population data were obtained using the US Census (2010). Analysis was conducted based on the following age categories: <5 yo, 5–9 yo, 10–14 yo, 15–19 yo and ≥20 yo. These age groups were chosen based on conventional US Census age categories and those used in similar studies. Average yearly incidence for each age category was calculated by dividing the total number of crashes by 7 (the number of years included in the study) and further dividing

[1] Illinois Texting Laws. http://www.distracteddrivinghelp.com/illionis-texting-laws (accessed 24 Sept, 2012).

[2] Illinois Graduated Driver Licensing Program Parent-Teen Driving Guide. http://www.cyberdriveillinois.com/publications/pdf_publications/dsd_a217.pdf (accessed 4 Oct, 2012).

[3] Teen Driver Safety Task Force. http://www.cyberdriveillinois.com/departments/drivers/teen_driver_safety/gdltaskforce.html (accessed 4 Oct, 2012).

by the age-specific Chicago population data from the US Census (2010). Driver population data were obtained using data from the Office of Highway Policy Information (Office of Highway Policy Information, 2010).

2.2. Definitions

Injury severity was based on assessment by law enforcement officers that may or may not have included interviews with medical personnel at the time of the crash. Categories for NHTSA codes are shown below and definitions come directly from the database code files.

1. Fatal
2. Severe – "Incapacitating injury – any injury other than fatal injury, which prevents the injured person from walking, driving, or normally continuing the activities he/she was capable of performing before the injury occurred. Includes severe lacerations, broken limbs, skull or chest injuries, and abdominal injuries."
3. Moderate – "Non-incapacitating injury – any injury other than fatal or incapacitating injury, which is evident to observers at the scene of the crash. Includes lump on head, abrasions, bruises, minor lacerations."
4. Minor – "Possible injury – any injury reported or claimed which is not either of the above injuries. Includes momentary unconsciousness, claims of injuries not evident, limping, complaint of pain, nausea, hysteria."
5. None – "None."

Considering that a very small proportion of pedestrians were reported as no injury (1.4% of pedestrians) and those with injuries that were not immediately visible may have been misclassified as no injury, the no injury category was combined with the minor injury category for analysis.

2.3. Data analysis

Data were analyzed with using Statistical Package for the Social Sciences 22.0 for Windows (SPSS Inc., Chicago, IL) and SAS (Cary, NC). Chi-square and Cochran–Armitage tests were used to assess statistical significance. Statistical significance was set at $p < 0.05$. For statistical tests, those having responses listed as "other" or "unknown" were excluded. Multivariate logistic regression analysis was performed separately for children and adults to estimate injury severity (fatal/severe versus moderate/minor) by pedestrian gender, light condition, road condition, weather condition, location on road, traffic control device, hit-and-run, and month category.

This study was deemed exempt by the Institutional Review Board at the Ann and Robert H. Lurie Children's Hospital of Chicago.

Table 1
Age-specific average yearly pedestrian injury, fatality, and case-fatality, Chicago, 2004–2010.

Age group	Pedestrians in crashes (n)	Injury incidence (per 100,000)	Fatality incidence (per 100,000)	Case-fatality (%)
<5 yo	635	48.8	0.8	1.7
5–9 yo	1800	140.1	1.6	0.9
10–14 yo	2237	194.3	0.7	0.4
15–19 yo	2503	195.5	1.0	0.5
Adults (≥20 yo)	16,398	117.3	2.0	1.7
Total	23,573	124.9	1.8	1.4

yo = years old.

3. Results

3.1. Age-based incidence and yearly trends

Average yearly incidence varied broadly based on age categories. There were 7175 child pedestrian injuries for an overall injury incidence of 146.6 per 100,000, fatality incidence of 1.1 per 100,000, and case-fatality of 0.7%. See Table 1 for specific subgroup variables.

When compared to older children, those <5 yo had the lowest average injury incidence but the highest average case-fatality rate, suggesting that younger child pedestrians are more likely to be killed when involved in a crash. For children 5–19 yo, injury incidence was higher than adults but fatality incidence was lower, suggesting these children sustain less fatal injuries than adults.

The injury incidence declined over time for all age groups (Cochran–Armitage trend $p < 0.0001$ for <5 yo, 5–9 yo, and 10–14 yo; $p < 0.05$ for 15–19 yo, $p = 0.96$ for ≥20 yo, Fig. 1). Case-

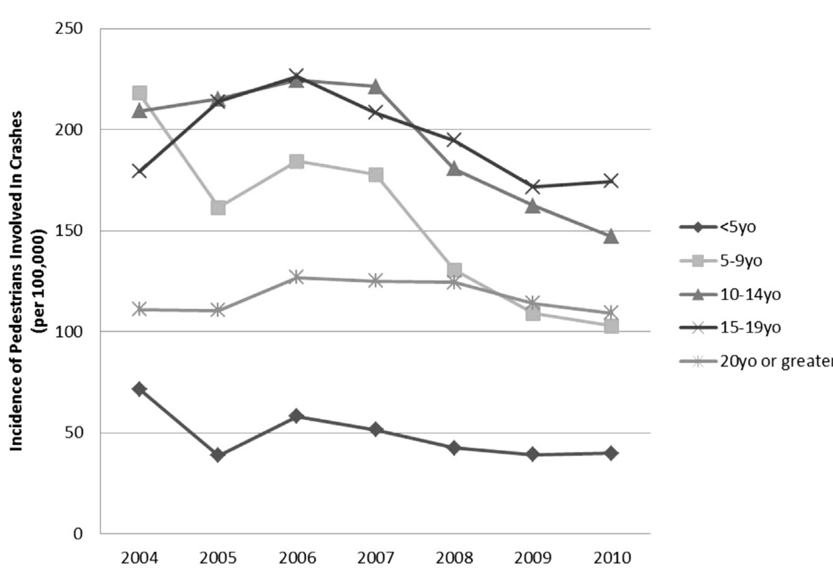

Fig. 1. Age specific pedestrian injury incidence trends, Chicago, 2004–2010.
yo = years old.
*Cochran–Armitage trend test $p < 0.0001$ for <5 yo, 5–9 yo, and 10–14 yo; $p < 0.05$ for 15–19 yo, $p = 0.96$ for >20 yo.

fatality rates did not follow a distinct pattern over time for children but decreased for adults (Cochran–Armitage trend $p < 0.001$ for those $\geq$20 yo only, unable to calculate for all other age groups due to small number of deaths).

3.2. Age-based crash characteristics

All of the crash characteristics studied followed statistically significant age-based trends (see Table 2).

The majority of injuries were considered to be minor or moderate for both child and adult pedestrians. Younger age associated with less severe injury, increased male predominance, more ideal light/road/weather conditions, more mid-block locations, lack of traffic control device, fewer hit-and-run crashes, and warmer months. See Fig. 2 for age-specific crash proportion broken down by month.

3.3. Crash characteristics associated with injury severity

As it would be most desirable to design interventions aimed at preventing the more serious injuries, we looked for age-based associations between injury severity and crash characteristic. Many of the crash characteristics studied associated with injury severity for both children and adults (see Table 3).

For both children and adults, more fatal injuries associated with male gender, darkness, mid-block location, and lack of traffic control device. In children, wet road conditions also associated with fatalities and in adults, hit-and-run crashes associated with fatalities. There were no significant differences in fatalities based on weather conditions or warm/cool months for either age group. When entered in a multivariate logistic regression model using fatal/severe versus moderate/minor injury as outcome, for child pedestrians, light condition remained significant (with less severe injuries being associated with daylight conditions, OR 0.93, 95% CI 0.88–0.98). For adults, when entered in a multivariate logistic regression model using fatal/severe versus moderate/minor injury as outcome, light condition and hit-and-run status remained significant. Specifically, injuries were less severe in daylight (OR 0.90, 95% CI 0.87–0.93) and non-hit-and-run (OR 0.84, 95% CI 0.77–0.93) conditions.

For those crashes where both intersection and traffic control device were known, the interaction of these two factors was studied. More severe injuries were more likely to be at a midblock location with no traffic control device (χ^2 $p < 0.001$, data not shown) versus intersection locations where there were functioning traffic control devices. Of all child pedestrian crashes, 91% of minor/moderate, 51% of severe, and 53% of fatal child pedestrian crashes occurred at midblock locations with no traffic control device. Conversely, 52% of minor/moderate, 23% of severe and 21% of fatal child pedestrian crashes occurred at intersections where traffic control devices were present and properly functioning. A similar trend was seen in adult pedestrian crashes (data not shown).

3.4. Characteristics of drivers in pedestrian versus auto crashes

To better understand the potential implications of changes in driving laws, we assessed basic driver characteristics. Average driver age in Chicago child pedestrian crashes was 39.0 yo (SE of Mean 0.23 yr) with a median age of 36 yo. Average driver age in Chicago adult pedestrian crashes was 40.8 yo (SE of Mean 0.16 yr) with a median age of 38 yo. Drivers in both Chicago child and adult pedestrian crashes were slightly over represented in the 20–29 yo and 30–39 yo categories compared to all licensed drivers in Illinois (χ^2 $p < 0.001$, see Appendix D). Whereas 49% of all licensed drivers in Illinois are male, drivers of Chicago pedestrian crashes were more likely to be male (59% and 57% in child and adult pedestrian crashes, respectively, χ^2 $p < 0.001$, see Appendix D). Most drivers in child pedestrian crashes (65% or 4436/6858) and adult pedestrian crashes (62% or 9741/15,802) were found to be in "normal" physical condition with <1% (39/6858) in child pedestrian crashes and 1% (180/15,802) in adult pedestrian crashes reported to be under the influence of drugs or alcohol at the time of the crash. Data on driver distraction were not consistently available in this dataset and therefore are not reported in this analysis. The majority of drivers in child (98% or 6712/6858) and adult (98% or 15,470/15,802) pedestrian crashes were reported to have no injuries resulting from the crash. None of the drivers in either child or adult pedestrian crashes were fatally injured.

4. Discussion

4.1. Pedestrian injury incidence and case-fatality implication

The child pedestrian injury incidence (146.6 per 100,000 overall) found in our study is lower than their adult counter parts. It is also lower than that found by authors a decade ago in New York City but higher than rates found in other locales (DiMaggio and Durkin, 2002; Chakravarthy et al., 2012; Rivara and Barber, 1985; Lee et al., 2009). These differences may reflect variation in local regulations or enforcement, road design, fleet characteristics, weather conditions, and pedestrian behavior. Appendix A online highlights some of the pedestrian injury prevention efforts and driving regulations implemented around the study period which may have influenced incidence rates. Variations in population density have also been suggested to affect pedestrian crash patterns (Chakravarthy et al., 2012; Sebert Kuhlmann et al., 2009; Zhu et al., 2008; Lascala et al., 2000). When prior studies were done in New York City, the population of children <19 yo was 2,028,159 (6701.6/square mile based on 302.64 square miles in New York City) while the population of children $\leq$19 yo in Chicago during our study was estimated to be 699,363 (3072.4/square mile based on 227.63 square miles in Chicago) (US Census, 2010; New York Vital Statistics, 1997). This supports the need for location specific data when developing prevention strategies, as incidence widely varies.

The fatality incidence (average rate 1.8 per 100,000) calculated in this study is higher than reported for the entire state of Illinois by FARS during the same time period (range 0.9–1.4 per 100,000).[4] Although Chicago makes up a large portion of Cook County, our incidence is also slightly higher than FARS data for Cook County alone (range 1.0–1.8 per 100,000) during the same time period. This may be due to differences in population density in Chicago versus the remainder of Cook County. It may also be due to the exclusion from analysis of the 1549 individuals for whom no age data was available. Further study outside the scope of this investigation is needed.

Case-fatality was similar to data from prior studies and did not show a consistent decrease over time (DiMaggio and Durkin, 2002; Nance et al., 2004). This may suggest that although we have been able to decrease child pedestrian crashes in general, there has not been any greater impact on fatal crashes versus less severe crashes. Further initiatives focused specifically on prevention of fatal crashes or pre-/post-crash interventions may prove beneficial.

4.2. Pedestrian injury trends over time

As seen in New York City a decade ago, injury incidence in our study decreased over time (DiMaggio and Durkin, 2002). However,

[4] Fatality Analysis Reporting System (FARS) Encyclopedia. http://www-fars.nhtsa.dot.gov/States/StatesPedestrians.aspx (accessed 29 Jan, 2014).

Table 2
Age-specific pedestrian crash characteristics, Chicago, 2004–2010.

	<5 yo N = 635 n (%)	5–9 yo N = 1800 n (%)	10–14 yo N = 2237 n (%)	15–19 yo N = 2503 n (%)	Adults ≥20 yo N = 16398 n (%)	Cochran–Armitage trend p
Injury severity*						
Killed	11 (2)	21 (1)	8 (0)	13 (1)	283 (2)	<0.01
Severe	93 (15)	268 (15)	313 (14)	357 (14)	2545 (16)	
Moderate	359 (57)	1032 (57)	1248 (56)	1314 (53)	7789 (48)	
Minor	172 (27)	479 (27)	668 (30)	819 (33)	5781 (35)	
Gender*						
Male	411 (65)	1125 (63)	1238 (55)	1183 (47)	8425 (51)	<0.0001
Female	220 (35)	644 (36)	965 (43)	1288 (52)	7790 (48)	
Unknown	4 (1)	31 (2)	34 (2)	32 (1)	183 (1)	
Light condition*						
Daylight	470 (74)	1416 (79)	1576 (71)	1523 (61)	9874 (60)	<0.0001
Dawn/dusk	33 (5)	103 (6)	167 (8)	126 (5)	741 (5)	
Darkness	123 (19)	257 (14)	461 (21)	816 (33)	5551 (34)	
Unknown	9 (1)	24 (1)	33 (2)	38 (2)	232 (1)	
Road condition*						
Dry	545 (86)	1462 (81)	1776 (79)	1845 (74)	11692 (71)	<0.0001
Wet	56 (9)	200 (11)	296 (13)	437 (18)	3273 (20)	
Snow/ice	6 (1)	39 (2)	73 (3)	96 (4)	682 (4)	
Other/unk	28 (4)	99 (6)	92 (4)	125 (5)	751 (5)	
Weather condition*						
Clear	562 (89)	1572 (87)	1862 (83)	1958 (78)	12466 (76)	<0.0001
Rain	39 (6)	124 (7)	213 (10)	320 (13)	2263 (14)	
Snow/sleet/fog	14 (2)	57 (3)	99 (4)	139 (6)	1155 (7)	
Other/unk	20 (3)	47 (3)	63 (3)	86 (3)	514 (3)	
Location on road*						
Intersection	187 (29)	534 (30)	987 (44)	1378 (55)	8898 (54)	<0.0001
Mid-block	448 (71)	1266 (70)	1250 (56)	1125 (45)	7500 (46)	
Traffic control device*						
Properly functioning	130 (21)	346 (19)	664 (30)	1024 (41)	7140 (44)	<0.0001
Broken	10 (2)	30 (2)	82 (4)	97 (4)	742 (5)	
Not present	458 (72)	1308 (73)	1328 (59)	1183 (47)	7289 (45)	
Other/unk	37 (6)	116 (6)	163 (7)	199 (8)	1227 (8)	
Hit & run*						
Yes	143 (23)	427 (24)	699 (31)	1027 (41)	5591 (34)	<0.0001
No	492 (78)	1373 (76)	1538 (69)	1476 (59)	10807 (66)	
Month*						
Warm	470 (74)	1225 (68)	1255 (56)	1329 (53)	7863 (48)	<0.0001
Cool	165 (26)	575 (32)	983 (44)	1174 (47)	8535 (52)	

yo = years old; unk = unknown.
Warm months = April–September; Cool months = October–March.
* χ^2 $p < 0.001$, Other/unk excluded from χ^2 analysis.

during our study period national trends show that personal electronic device use has increased and studies have shown that these devices lead to more risky pedestrian and driver behaviors (Lenhart, 2012; Stavrinos et al., 2009, 2011; Schwebel et al., 2012; Nasar et al., 2008; Lichenstein et al., 2012; Thompson et al., 2012; Young et al., 2012; Neyens and Boyle, 2007; Smith, 2010; Ishigami and Klein, 2009; Klauer et al., 2013; Caird et al., 2008). While pedestrian deaths due to distracted driving are reportedly on the rise, we were unable to test this in our population because driver distraction was not consistently reported (Stimpson et al., 2013; Wilson and Stimpson, 2010). Perhaps prevention efforts designed to decrease distracted driving are working to suppress a rise in pedestrian crashes overall as seen in other studies (McCartt et al., 2014; Lim and Chi, 2013).[1,2,3] Declining incidence over time may also reflect diminishing outdoor activity time in children and adolescents as suggested by other studies (Clements, 2004; Hofferth and Sandberg, 2001). Our data does not allow us to specifically assess each of these potential correlations but rather describes crash trends in the setting of these multifactorial changes.

4.3. Crash characteristics compared to prior studies

Many child pedestrian crash characteristics during this study period followed similar trends to those seen previously in other locations. Crashes in our study peaked during warm months in younger age groups as opposed to older, showed predominance in males that decreased with the child's age, and occurred during favorable light, road, and weather conditions. Although the majority of children were hit mid-block, as age increased children became more likely to be hit at an intersection. Most accidents occurred at sites where there were no traffic control devices or the device was broken. These characteristics are similar to those found in other studies prior (DiMaggio and Durkin, 2002; Centers for Disease Control and Prevention Morbidity and Mortality Weekly Report, 2013; Stimpson et al., 2013; Slaughter et al., 2014; Rothman

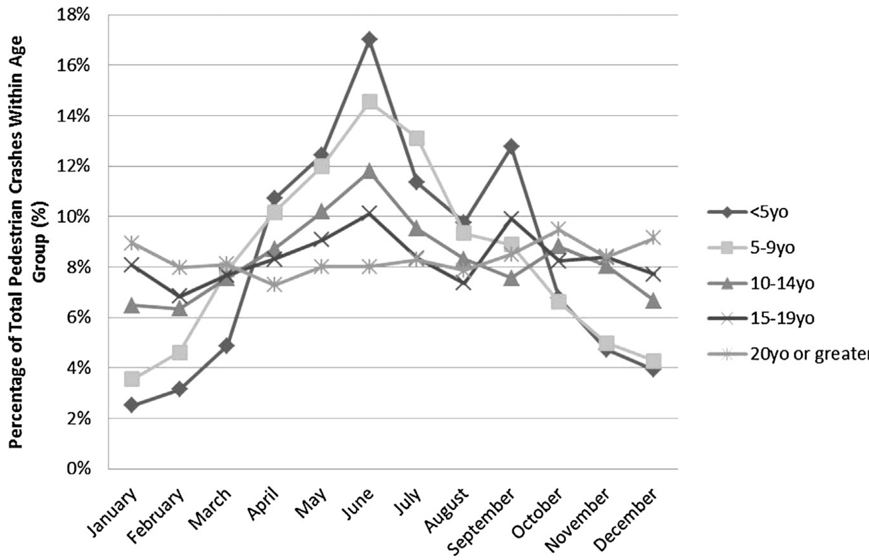

Fig. 2. Age-specific distribution of pedestrian injury by month, Chicago, 2004–2010.
yo = years old.
*χ^2 $p < 0.001$ with warm months (April–September) versus cool months (October–March) by age.

Table 3
Pedestrian crash characteristics based on injury severity, Chicago, 2004–2010.

	Child (≤19 yo) N = 7175			Adult (≥20 yo) N = 16,398		
	Fatal	Severe	Moderate/minor	Fatal	Severe	Moderate/minor
Gender	χ^2 $p < 0.05$			χ^2 $p < 0.001$		
Male	38 (72)	589 (57)	3330 (55)	180 (64)	1326 (52)	6919 (51)
Female	15 (28)	425 (41)	2677 (44)	103 (36)	1185 (47)	6502 (48)
Unknown	0 (0)	17 (2)	84 (1)	0 (0)	34 (1)	149 (1.1)
Light condition	χ^2 $p < 0.01$[a]			χ^2 $p < 0.001$		
Daylight	31 (59)	706 (69)	4248 (70)	120 (42)	1452 (57)	8302 (61)
Dawn/dusk	1 (2)	47 (5)	381 (6)	10 (4)	112 (4)	619 (5)
Darkness	21 (40)	266 (36)	1370 (23)	152 (54)	952 (37)	4447 (33)
Unknown	0 (0)	12 (1)	92 (2)	1 (0)	29 (1)	202 (2)
Road condition	χ^2 $p < 0.05$[a]			χ^2 $p = 0.28$		
Dry	43 (81)	837 (81)	4748 (78)	213 (75)	1855 (73)	9624 (71)
Wet	9 (17)	140 (14)	840 (14)	53 (19)	519 (20)	2701 (20)
Snow/ice	0 (0)	16 (2)	198 (3)	11 (4)	88 (4)	583 (4)
Other/unk	1 (2)	38 (4)	305 (5)	6 (2)	83 (3)	662 (5)
Weather condition	χ^2 $p = 0.67$[a]			χ^2 $p = 0.62$		
Clear	46 (87)	862 (84)	5046 (83)	228 (81)	1946 (77)	10292 (76)
Rain	6 (11)	91 (9)	599 (10)	38 (13)	359 (14)	1866 (14)
Snow/sleet/fog	0 (0)	44 (4)	265 (4)	14 (5)	177 (7)	964 (7)
Other/unk	1 (2)	34 (3)	181 (3)	3 (1)	63 (3)	448 (3)
Location on road	χ^2 $p < 0.05$			χ^2 $p < 0.001$		
Intersection	20 (38)	404 (39)	2662 (44)	118 (42)	1352 (53)	7428 (55)
Mid-block	33 (62)	627 (61)	3429 (56)	165 (58)	1193 (47)	6142 (45)
Traffic control device	χ^2 $p < 0.01$[a]			χ^2 $p < 0.001$[a]		
Properly functioning	41 (26)	295 (29)	1855 (31)	110 (39)	1090 (43)	5940 (44)
Broken	0 (0)	31 (3)	188 (3)	3 (1)	123 (5)	616 (5)
Not present	36 (68)	643 (62)	3598 (59)	157 (56)	1185 (47)	5947 (44)
Other/unk	3 (6)	62 (6)	450 (7)	13 (5)	147 (6)	1067 (8)
Hit & run	χ^2 $p = 0.08$			χ^2 $p < 0.001$		
Yes	21 (40)	303 (29)	1972 (32)	124 (44)	779 (31)	4688 (35)
No	32 (60)	728 (71)	4119 (68)	159 (56)	1766 (69)	8882 (66)
Month	χ^2 $p = 0.44$			χ^2 $p = 0.91$		
Warm	35 (66)	627 (61)	3617 (59)	132 (47)	1221 (48)	6510 (48)
Cool	18 (34)	404 (39)	2474 (41)	151 (53)	1324 (52)	7060 (52)

yo = years old; unk = unknown.
Other/unknown excluded from χ^2 analysis.
Warm months = April–September; Cool months = October–March.
[a] Yate's correction applied.

et al., 2012; Nance et al., 2004; Warsh et al., 2009; Weiner and Tepas, 2009). As other studies have shown, our data also found that injuries were more severe at midblock locations for both child and adult pedestrians (Slaughter et al., 2014; Rothman et al., 2012). However, the proportion of hit-and-run crashes in our data (23–41% varying by age) is higher than the reported national rate of 18% (MacLeod et al., 2012). This may be due to the fact our data include only crashes within a major metropolitan location. Further study is needed.

4.4. Injury prevention implications

These data can be used to inform injury prevention initiatives. Specifically, studies have recently shown the utility of video, internet, and training in a virtual environment to improve safe street crossing in children (Arbogast et al., 2014; Schwebel et al., 2014a,b). Our data can be used to help inform how to create simulated environments to match the most common crash characteristics for the age group that is being educated. Alternatively, these data provide age-based guidance for built environments. For example, areas near schools or play areas where there are a large number of small children, mid-block changes to the built environment may be more efficacious than making the same changes in an environment where there are mainly adults.

4.5. Limitations

One potential limitation of this study is that outcomes are only as accurate as the data entered into the database. While some suggest that Chicago crash reports may contain errors, NHTSA data is the most inclusive currently available way to assess large-scale child pedestrian injury. Another limitation is that 2010 US Census data were used as an estimate for population for each year and to calculate yearly incidence. The 2010 US Census data were used to compute incidence because to our knowledge, there are no better sources available for the individual years of the study that provide population data broken down to the age groups we included. Actual population from year to year may have varied slightly from year to year but would not be expected to significantly change results. Additionally, this study is based only on data from pedestrian crashes that were reported to law enforcement. This has the potential to underestimate true pedestrian crash incidence, as crashes taking place on private property (such as roll-over injuries in driveways) may not be as consistently reported. However, these likely make up a very small fraction of all child pedestrian crash cases and are therefore unlikely to limit the data presented in this analysis. Using NHTSA data may also lead to an over-representation of the most severe crashes. Fourth, injury severity ratings in this study are based on report by law officers with or without assessment from medical personal and may under- or over-estimate true injury severity. Finally, only cases for which pedestrian age was available were included in analysis. Data for those where age was not available varied from included cases in injury service, gender, location, traffic control device presence, and hit-and-run status. It is impossible to know how results would be modified if these data were included.

5. Conclusions

While incidence of child but not adult pedestrian versus auto crashes has decreased over the last five years of the study, case fatality and crash characteristics are similar to those seen in other urban settings previously. Many pedestrian crash characteristics follow age-specific trends that vary from those of adult pedestrian crashes. Injuries tend to be less severe during daylight conditions. These data can be used to guide our targeted injury prevention and education efforts.

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Appendix A.

See Table A1.

Table A1
Timeline of legislation and technology developments surrounding study period.

2003	• Chicago red light camera implementation[a]
2004	• Nationally, 45% of children 12–17 yo own cellphones[b]
2005	• Chicago cellphone ban. Drivers only allowed to use hands-free cellphone devices while driving ($75 fine, $200 if in accident)[c] • Nationally, 11% of adults own MP3 players[d]
2006	• Safe streets for Chicago development with goals to: 1) Create Mayor's Pedestrian Advisory Council 2) Initiate cross-walk awareness campaign for drivers 3) Add pedestrian countdown signals to all new traffic signals and to start retro-fitting existing devices[e] • Nationally, 63% of children 12–17 yo own cellphones[b]
2007	• Illinois Graduated Driver License legislation introduced[f]
2008	• January – Chicago bans school bus drivers and young drivers from using any cellphone device (including hands free) while driving[c] • October – Chicago bans texting while driving[c] • Nationally, 71% of children 12–17 yo own cellphones; 74% own an iPOD or MP3 player[b]
2009	• February – Chicago increases fine for cellphone use while driving to $100 ($500 if involved in accident while using cellphone)[c] • New provisions for Illinois Graduated Driver License legislation[g]
2010	• Illinois distracted driving law goes into effect: 1) Illegal to email/text/surf the internet while driving 2) No talking on cellphone in work or school zone 3) Drivers less than 18 yo may not use any cellphone while driving (including hands-free devices)[c] • Nationally, 85% of adults own cellphones; 47% own an iPOD or MP3 player[d]

2011 • Illinois Distracted Driving Summit and "Drive Now Text Later" Campaign[c]
• December – Chicago pedestrian safety campaign installs crossing flags[h]

2012 • July – Illinois strengthens distracted driving legislation:
1) Bans commercial drivers from texting or hand-held cellphone devices
2) Bans any cellphone used (including hands-free) in any work zone
3) Bans cellphone use within 500 feet of an emergency scene[i]
• July – Chicago DOT installs "Stop for Pedestrian" signs at crosswalks[h]
• September – Chicago Pedestrian Plan released

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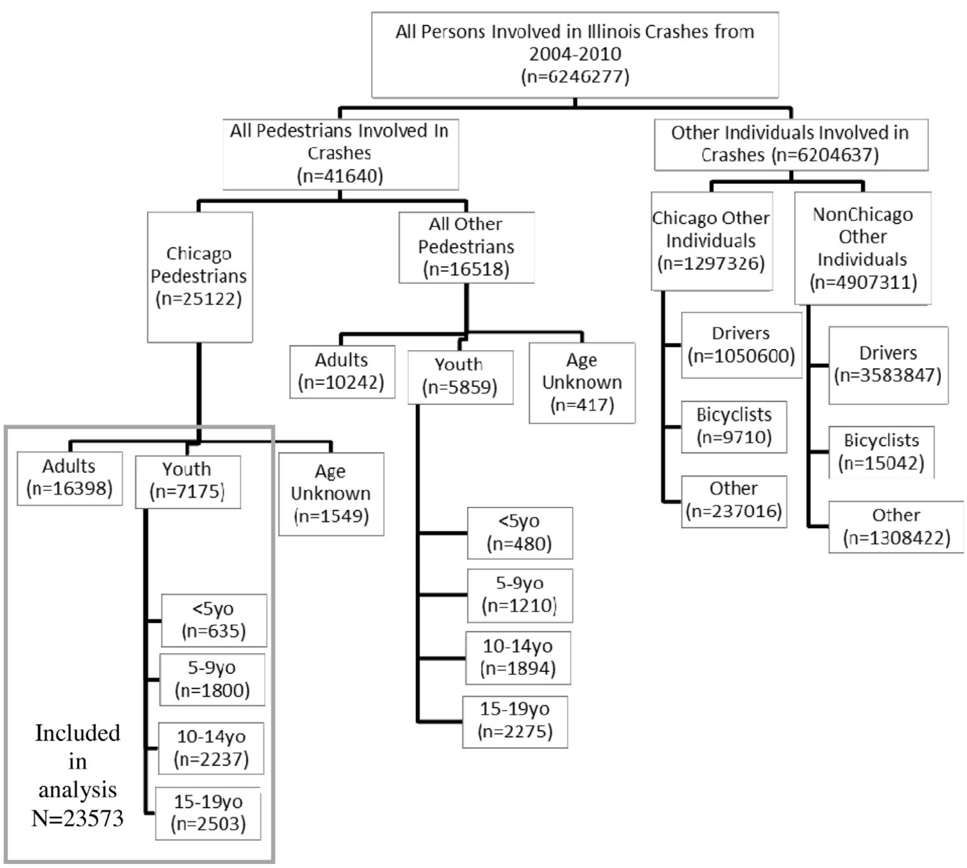
[a] Red-Light Camera Enforcement. City of Chicago. http://www.cityofchicago.org/city/en/depts/cdot/supp_info/red-light_cameraenforcement.html (accessed 24 Sept, 2012).
[b] Lenhart A. Teens and Social Media: An Overview. Pew Internet and American Life Project Report, April 10, 2009. http://isites.harvard.edu/fs/docs/icb.topic603902.files/Teens%20Social%20Media%20and%20Health%20-%20NYPH%20Dept%20Pew%20Internet.pdf (accessed 1 Oct, 2012).
[c] Illinois Texting Laws. http://www.distracteddrivinghelp.com/illinois-texting-laws (accessed 24 Sept 2012).
[d] Smith A. Americans and their Gadgets. Pew Internet and American Life Project Report, October 14, 2010. http://pewinternet.org/~/media//files/reports/2010/PIP-Americans%20and%20their%20gadgets.pdf (accessed 1 Oct, 2012).
[e] Safe Streets for Chicago. City of Chicago. http://www.cityofchicago.org/city/en/depts/cdot/supp_info/safe_streets_forchicago.html (accessed 24 Sept, 2012).
[f] Teen Driver Safety Task Force. http://www.cyberdriveillinois.com/departments/drivers/teen_driver_safety/gdltaskforce.html (accessed 4 Oct, 2012).
[g] Illinois Graduated Driver Licensing Program Parent-Teen Driving Guide. http://www.cyberdriveillinois.com/publications/pdf_publications/dsd_a217.pdf (accessed 4 Oct, 2012).
[h] What We Do. City of Chicago. http://www.cityofchicago.org/city/en/depts/cdot/provdrs/ped.html (accessed 24 Sept, 2012).
[i] Illinois: Cellphone and texting laws, legislation. http://handsfreeinfo.com/illinois-cell-phone-laws-legislation (accessed 24 Sept, 2012).

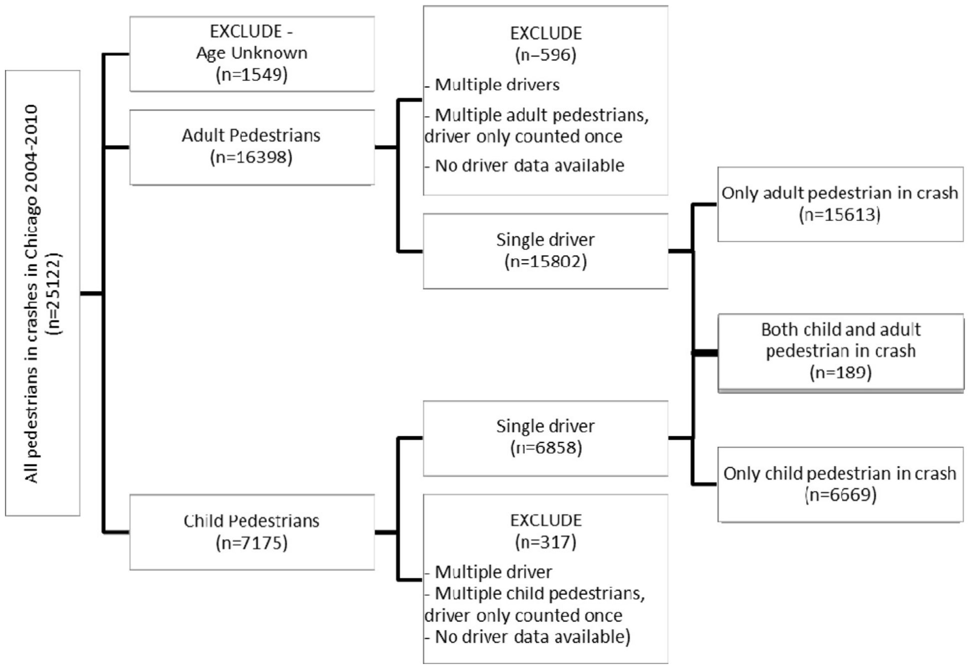
Appendix B.

Pedestrian inclusion and exclusion criteria for 2004–2010.



Appendix C.

Driver analysis exclusion criteria.



Appendix D.

See Table D1.

Table D1
Chicago 2004–2010 pedestrian crash driver characteristics compared to all licensed drivers in Illinois.[a]

	Drivers in Chicago child pedestrian crashes *n* (%)	Drivers in Chicago adult pedestrian crashes *n* (%)	All licensed drivers of Illinois *n* (%)
Age category (years)[b]	*N* = 4541	*N* = 10,062	*N* = 8,373,969
16–19	284 (6)	455 (5)	429,355 (5)
20–29	1264 (28)	2581 (26)	1,445,443 (17)
30–39	1059 (23)	2276 (23)	1,441,414 (17)
40–49	781 (17)	1854 (18)	1,570,542 (19)
50–59	615 (14)	1529 (15)	1,566,105 (19)
60–69	333 (7)	789 (8)	1,068,993 (13)
70–79	162 (4)	395 (4)	566,618 (7)
≥80	43 (1)	183 (2)	285,499 (3)
Gender[c]	*N* = 4987	*N* = 11,124	*N* = 8,373,969
Male	2957 (59)	7450 (67)	4,122,828 (49)
Female	2030 (41)	3674 (33)	4,251,141 (51)

[a] There were 189 drivers who hit both a child and an adult pedestrian.
[b] The minimum age to obtain a driver's permit in Illinois is 15 yo: 6 drivers in child pedestrian crashes and 5 in adult pedestrian crashes were <15 yo and 7 drivers in child pedestrian crashes and 5 in adult pedestrian crashes were 15 yo. χ^2 analysis was done only on drivers ≥16 yo. For age, χ^2 $p < 0.001$, for both drivers in child and drivers in adult pedestrian crashes compared to all other licensed drivers in Illinois.
[c] χ^2 $p < 0.001$ for both drivers in child and drivers in adult pedestrian crashes compared to all other licensed drivers in Illinois.

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