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EPIDEMIOLOGY | RESEARCH ARTICLE

Morbidity and mortality patterns of pedestrian injuries by age at the Puerto Rico Trauma Hospital from 2000 to 2014

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Abstract: This study evaluates morbidity and mortality patterns of 2,093 pedestrian injuries at the Puerto Rico Trauma Hospital during 2000–2014 by age. Most were male between the ages of 35–64, with the highest occurrence of injuries during 8pm-4am. The most common injury was lower extremity injuries (46.6%), followed by intracranial injuries (35.5%), except in the youngest age group where the opposite pattern was observed. Pedestrians in the 65–74 and 75–84 age groups had a greater proportion of upper extremity fractures (31.1% and 32.7%, respectively) and those in the 55–64 and 65–74 groups had a higher proportion of lower extremity fractures (43.8%), compared to the youngest group. Hepatic injuries (13.4%) commonly affected subjects <16 years, whereas older patients frequently sustained rib, sternum, larynx and trachea fractures. Compared to the youngest group, the risk of death increased 14-fold (95%CI: 5.90, 33.18) and 24.6-fold (95%CI: 8.10, 74.41) in those aged 65–74 and older than 84, respectively. Given these findings, implementing pedestrian safety legislation, educational programs, urban planning and preventive measures must be tailored to the needs of each age group.

ABOUT THE AUTHORS

Pablo Rodríguez-Ortiz The Trauma Research Program from the Puerto Rico Trauma Hospital is a clinical and epidemiological study center devoted to generate scientific knowledge focusing on trauma to optimize preventive, therapeutic and rehabilitative services for trauma patients in order to improve their life quality. Our program is composed of a multidisciplinary team of researchers that includes trauma surgeons, physicians, medical residents, medical students, biostatisticians, epidemiologists, public health experts, and undergraduate students. Previous relevant works include the only study describing the epidemiology of injuries in Puerto Rico, the assessment of the effect of seatbelts use on mortality secondary to road traffic collisions, and the evaluation of the impact of diabetes mellitus on complications and trauma mortality.

PUBLIC INTEREST STATEMENT

The increased presence of motor vehicles in cities has created a life-threatening public health issue affecting the most vulnerable population: pedestrians. This study evaluates morbidity and mortality patterns of pedestrian injuries by age admitted to the Puerto Rico Trauma Hospital, the only trauma hospital in Puerto Rico and many islands in the Caribbean. From 2000 to 2014, most injured pedestrians were male between the ages of 35–64 and specific bodily injuries are associated with the person's age. Older pedestrians sustained upper and lower extremity fractures more frequently than younger patients, which sustained greater hepatic and splenic injuries. Alarmingly, the risk of death increased 14-fold and 24.6-fold in patients aged 65–74 years and older than 84, respectively, compared to those younger than 16. Owing to these findings, implementing pedestrian safety legislation, educational programs, urban planning and preventive measures must be tailored to the needs of each age group.

Subjects: Public Health Policy and Practice; Epidemiology; Trauma

Keywords: trauma; pedestrian injuries; road-traffic injuries; pedestrian mortality; traffic safety

1. Introduction

The increased presence of motor vehicles in urban areas created serious public health issues (Törő, Hubay, Sótonyi, & Keller, 2005). Recent global estimates report that more than 1.25 million people are killed in traffic accidents, becoming the leading causes of death for people aged between 15 and 29 years (World Health Organization [WHO], 2015). Furthermore, males under the age of 25 are 3 times more likely to suffer fatal pedestrian injuries than their female counterparts (WHO, 2015). More than half of the world's traffic deaths are among pedestrians; nearly 90% of these fatalities occur in low and middle-income countries (Eid & Abu-Zidan, 2015; Nantulya & Reich, 2002; WHO, 2015). Without the appropriate interventions, fatalities may increase up to 2.4 million by 2030 (Eid & Abu-Zidan, 2015; WHO, 2015).

Global estimates report that between 20 and 50 million people suffer non-fatal injuries, resulting in disability (WHO, 2015). Moreover, in 2015 approximately 129,000 Americans suffered from non-fatal pedestrian injuries in the United States (US) (Centers for Disease Control and Prevention [CDC], 2015). The US Department of Transportation reported 5,376 pedestrians were killed in traffic accidents in 2015 (National Highway Traffic Safety Administration, 2015). These statistics made pedestrian mortality the second largest cause of motor vehicle deaths in urban cities (Ballesteros, Dischinger, & Langenberg, 2004; Siram et al., 2011). Recent studies have shown that almost half of pedestrian deaths are children younger than 15 years of age and more than one-fourth are people 65 and older (Baker, O'Neill, Ginsburg, & Li, 1991; Vestrup & Reid, 1989).

The risk factors associated with pedestrian trauma include alcohol consumption and age (Del Rio & Alvarez, 1990; Vestrup & Reid, 1989). Studies have reported that pedestrian vs. motor-vehicle accidents are characterized by a high incidence of injuries in intoxicated adult males (Del Rio & Alvarez, 1990; Holubowyez, 1995; Nordrum, Eide, & JLrgensen, 2000; Small, Sheedy, & Garbs, 2006). Regarding age, pedestrians 65 and older are 6–8 times more likely to die than younger pedestrians due to higher rates of fractures and severe head injuries after trauma (Demetriades et al., 2004; Harruff, Avery, & Alter-Pandya, 1998; Lane, McClafferty, & Nowak, 1994; Sklar, Demarest, & McFeeley, 1989; Small et al., 2006). Additionally, pedestrians who suffer severe trauma from accidents of this nature are often injured in their lower extremities and head (The American College of Surgeons, Committee on Trauma, 1997; Brainard, Slauterbeck, Benjamin, Hagaman, & Higie, 1989; Li, Fan, & Yin, 2015; Siram et al., 2011; Small et al., 2006; Starnes, Hadjizacharia, Chan, & Demetriades, 2011; Vestrup & Reid, 1989; Winn, Agran, & Castillo, 1991; Yoganandan, Nahum, & Melvin, 1993).

In Puerto Rico, cars and automobiles are the most common mode of transportation (Poveda, 2018). Puerto Rico's road infrastructure is based on a central highway fed by several main asphalt roads from urban areas. A 100-mile-long by 35-mile-wide Island with 3.3 million inhabitants and over 3 million registered vehicles directly translates to highly congested and accident-prone traffic in cities (García, Torres, & Delgado, 2014; Poveda, 2018). As for road safety in Puerto Rico, the Vehicle and Transit Law 22 of Puerto Rico delineates road traffic information like zone speed limits, the duties of both conductors and pedestrians, and the legal limit for driving under the influence of alcohol (0.8%), but no specifications for alcohol consumption by pedestrians are included (Ley de Vehículos y Tránsito de Puerto Rico, 2001). Nevertheless, road traffic safety regulation and legislation reforms have remained stagnant (Colcucci Ríos, 2014).

Similarly, there is scarce information about pedestrian injuries in Puerto Rico. In population statistics from 2011 to 2013, males accounted for 80% of all pedestrian deaths and 34% were 39 years old and younger (Instituto de Estadísticas de Puerto Rico [IEPR], 2018). Even though from 2016 to 2017 there was a 65% decrease in pedestrian fatalities (from 100 to 38 deaths), they became the leading cause of traffic related deaths in Puerto Rico by 2017 (IEPR, 2018). The only study about the epidemiology of trauma in Puerto Rico showed that pedestrian injuries are sustained mostly by people between the ages of 40–64, whereas trauma from gunshot wounds, stab wounds, or road traffic collisions tend to occur in a younger population (18–39 years) (Pascual-Marrero, Ramos-Mel éndez, García-Rodríguez, Morales-Quiñones, Rodríguez-Ortiz, 2017). These differences of age among the mechanisms of trauma suggest that age is a risk factor for sustaining specific types of trauma. Pedestrians not only constitute an older trauma population, but also have the worst clinical outcomes (compared to the other mechanisms of trauma), including the highest in-hospital mortality rate with 19% in Puerto Rico (Pascual-Marrero et al., 2017).

Most pedestrian accident reports fail to describe pedestrian injury patterns and risks, only focusing on fatalities, disclosing a limited and narrow understanding about this public health threat. Due to the lack of data on this topic and the scarcity of pedestrian safety legislation, this study aimed to describe morbidity and mortality patterns of pedestrian injuries by age in Puerto Rico. The knowledge of these patterns will provide a basis for direction of resources, injury prevention programs, pre-hospital and hospital patient care protocols, and coordination of citywide trauma care.

2. Materials and methods

A cross-sectional retrospective analysis was conducted at the Puerto Rico Trauma Hospital (PRTH), a 24/7 operating teaching hospital and the only tertiary referral center that provides trauma care to Puerto Rico and the Caribbean. The subject data were recovered from the Trauma Registry of the hospital, a branch of the National Trauma Registry System (in the US), which contains an archive of all patient related information directly transcribed from medical records by trained personnel. Quarterly quality control is conducted on the Registry, in compliance with the standards and requirements of the American College of Surgeons. The International Classification of Diseases, Ninth Revision, (ICD-9) system's E-codes or external cause of injury codes, used by health providers to characterize and standardize health events, was the diagnostic standard used to include all pedestrian injuries in the PRTH (Injury Severity Score [NSW Institute of Trauma and Injury Management], 2008).

2.1. Population

We included in the study all the patients admitted to the hospital from January 2000 to December 2014 with the following E-Codes (which correspond to pedestrian related injuries): 806.2 (other specified railway accident injuring pedestrian), 812.7 (other motor vehicle traffic accident involving collision with motor vehicle injuring pedestrian), 813.7 (motor vehicle traffic accident involving collision with other vehicle injuring pedestrian), and 814.7 (motor vehicle traffic accident involving collision with pedestrian injuring pedestrian). Subsequently, the total number of patients was divided into nine categories of age to assess its role in the pedestrian injury patterns, following the categorization used by a previous study in this topic (Siram et al., 2011): <16, 16–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75–84, >84.

2.2. Variables

Patient specific data such as sociodemographic characteristics, drug use, and physiological variables measured on arrival to the hospital were retrieved. The sociodemographic variables measured were age and sex. Other patient specific variables gathered were alcohol use, trauma hour and weekday/end. The specific injury types categorized by body regions were defined by ICD-9 codes, as seen in Table 1. The study outcomes were injury severity score, Glasgow coma scale, hospital length of stay (measured in days), trauma intensive care unit length of stay (measured in days), and in-hospital mortality.

"The injury severity score is an anatomical scoring system that provides an overall score for patients with multiple injuries" (Trauma Scoring: Injury Severity Score). This system has proven

Table 1. Patient and injury characteristics by age categories

Age (years)	< 16 n (%)	16–24 n (%)	25–34 n (%)	35–44 n (%)	45–54 n (%)	55–64 n (%)	65–74 n (%)	75–84 n (%)	>84 n (%)	All ages n (%)	*p*
Total	**217 (10.37)**	**201 (9.60)**	**258 (12.33)**	**340 (16.24)**	**362 (17.30)**	**308 (14.72)**	**219 (10.46)**	**153 (7.31)**	**35 (1.67)**	**2,093 (100)**	
Characteristic											
Sex											
Male	149 (68.66)	145 (72.14)	213 (82.56)	273 (80.29)	297 (82.04)	239 (77.60)	154 (70.32)	108 (70.59)	26 (74.29)	1,604 (76.64)	<0.001
Female	68 (31.34)	56 (27.86)	45 (17.44)	67 (19.71)	65 (17.96)	69 (22.40)	65 (29.68)	45 (29.41)	9 (25.71)	489 (23.36)	
Trauma Hours											
1am-4am	32 (14.75)	58 (29.00)	52 (20.23)	83 (24.48)	84 (23.27)	69 (22.48)	37 (16.89)	23 (15.03)	3 (8.57)	441 (21.12)	<0.001
5am-8am	8 (3.69)	43 (21.50)	47 (18.29)	55 (16.22)	55 (15.24)	35 (11.40)	32 (14.61)	19 (12.42)	6 (17.14)	300 (14.37)	
9am-12pm	16 (7.37)	21 (10.50)	35 (13.62)	52 (15.34)	44 (12.19)	37 (12.05)	30 (13.70)	19 (12.42)	5 (14.29)	259 (12.40)	
1pm-4 pm	31 (14.29)	25 (12.50)	30 (11.67)	45 (13.27)	54 (14.96)	42 (13.68)	47 (21.46)	24 (15.69)	6 (17.14)	304 (14.56)	
5pm-8pm	52 (23.96)	12 (6.00)	28 (10.89)	38 (11.21)	40 (11.08)	47 (15.31)	28 (12.79)	38 (24.84)	9 (25.71)	292 (13.98)	
8pm-12am	78 (35.94)	41 (20.50)	65 (25.29)	66 (19.47)	84 (23.27)	77 (25.08)	45 (20.55)	30 (19.61)	6 (17.14)	492 (23.56)	
Trauma Days											
Monday	28 (12.90)	32 (15.92)	34 (13.18)	62 (18.24)	63 (17.40)	39 (12.66)	39 (17.81)	26 (16.99)	8 (22.86)	331 (15.81)	0.003
Tuesday	28 (12.90)	24 (11.94)	33 (12.79)	33 (9.71)	31 (8.56)	42 (13.64)	34 (15.53)	30 (19.61)	5 (14.29)	260 (12.42)	
Wednesday	37 (17.05)	18 (8.96)	35 (13.57)	43 (12.65)	38 (10.50)	41 (13.31)	39 (17.81)	19 (12.42)	4 (11.43)	274 (13.09)	
Thursday	31 (14.29)	23 (11.44)	26 (10.08)	36 (10.59)	44 (12.15)	42 (13.64)	34 (15.53)	22 (14.38)	6 (17.14)	264 (12.61)	
Friday	38 (17.51)	23 (11.44)	39 (15.12)	37 (10.88)	52 (14.36)	42 (13.64)	30 (13.70)	22 (14.38)	4 (11.43)	287 (13.71)	
Saturday	25 (11.52)	34 (16.92)	40 (15.50)	61 (17.94)	65 (17.96)	51 (16.56)	19 (8.68)	18 (11.76)	6 (17.14)	319 (15.24)	
Sunday	30 (13.82)	47 (23.38)	51 (19.77)	68 (20.00)	69 (19.06)	51 (16.56)	24 (10.96)	16 (10.46)	2 (5.71)	358 (17.10)	
Trauma Days											
Weekdays	124 (57.14)	97 (48.26)	128 (49.61)	174 (51.18)	176 (48.62)	164 (53.25)	146 (66.67)	97 (63.40)	23 (65.71)	1,129 (53.94)	<0.001
Weekends	93 (42.86)	104 (51.74)	130 (50.39)	166 (48.82)	186 (51.38)	144 (46.75)	73 (33.33)	56 (36.60)	12 (34.29)	964 (46.06)	

(*Continued*)

Table 1. (*Continued*)

Age (years)	< 16 n (%)	16–24 n (%)	25–34 n (%)	35–44 n (%)	45–54 n (%)	55–64 n (%)	65–74 n (%)	75–84 n (%)	>84 n (%)	All ages n (%)	*p*
Ethanol											
Yes	4 (5.41)	5 (5.75)	19 (14.73)	20 (12.42)	30 (16.48)	20 (18.02)	10 (11.36)	6 (10.00)	0	114 (12.58)	0.047
No	70 (94.59)	82 (94.25)	110 (85.27)	141 (87.58)	152 (83.52)	91 (81.98)	78 (88.64)	54 (90.00)	14 (100.00)	792 (87.42)	
LOS (days)											
Med. (IQR)	8 (12)	10 (15)	10 (20)	12 (24)	15 (27)	14 (26)	14 (29)	14 (29)	13 (24)	12 (23)	<0.001
TICU LOS (days)											
Med. (IQR)	4 (10)	12.5 (17)	16 (22)	16 (15)	17 (22)	19 (14)	22.5 (21.5)	12 (18)	10 (18)	16 (19)	<0.001
GCS											
<9	46 (25.00)	47 (26.11)	63 (27.51)	81 (27.55)	81 (25.16)	69 (24.56)	32 (17.20)	20 (14.49)	9 (28.13)	448 (24.27)	0.042
≥9	138 (75.00)	133 (73.89)	166 (72.49)	213 (72.45)	241 (74.84)	212 (75.44)	154 (82.80)	118 (85.51)	23 (71.88)	1,398 (75.73)	
ISS											
≥ 25	55 (26.19)	81 (41.12)	93 (36.61)	131 (38.64)	145 (40.62)	124 (40.92)	97 (45.12)	61 (40.13)	17 (48.57)	804 (38.99)	0.008
16–24	56 (26.67)	54 (21.41)	86 (33.86)	106 (31.27)	98 (27.45)	85 (28.05)	57 (26.51)	45 (29.61)	6 (17.14)	593 (28.76)	
10–15	31 (14.76)	22 (11.17)	33 (12.99)	43 (12.68)	45 (12.61)	39 (12.87)	21 (9.77)	22 (14.47)	3 (8.57)	259 (12.56)	
1–9	68 (32.38)	40 (20.30)	42 (16.54)	59 (17.40)	69 (19.33)	55 (18.15)	40 (18.60)	24 (15.79)	9 (25.71)	406 (19.69)	
Death											
Yes	12 (5.53)	26 (12.94)	40 (15.50)	72 (21.18)	52 (14.36)	80 (25.97)	64 (29.22)	52 (33.99)	16 (45.71)	414 (19.78)	<0.001
No	205 (94.47)	175 (87.06)	218 (84.50)	268 (78.82)	310 (85.64)	228 (74.03)	155 (70.78)	101 (66.01)	19 (54.29)	1,679 (80.22)	

Weekdays: Monday, Tuesday, Wednesday, and Thursday; Weekends: Friday, Saturday, and Sunday; LOS: length of stay; Med: median; IQR; interquartile range; TICU: trauma intensive care unit; GCS: Glasgow Coma Scale; ISS: Injury Severity Score to have a high correlation with morbidity and mortality (Injury Severity Score [NSW Institute of Trauma and Injury Management], 2008). To assess for traumatic brain injury, the Glasgow coma scale describes the level of consciousness used to determine the prognosis of the patient (Teasdale, Jennett, Brennan, McElhinney, & Allan, 2014).

2.3. Statistical analysis

The descriptive statistical analysis was performed using medians and interquartile ranges (IQR) for continuous variables and absolute (n) and relative (%) frequencies for categorical variables. The bivariate analysis was done using the Pearson's chi-square test for categorical variables and the Kruskal-Wallis test for continuous ones. We performed post-hoc tests to evaluate differences between specific age groups. The results of post-hoc tests are not shown in tables.

A negative binomial regression was conducted to assess the relationship between age categories and hospital length of stay and trauma intensive care unit length of stay. Additionally, a logistic regression analysis was performed to evaluate association between age categories and in-hospital mortality, adjusting for sex, injury severity score, and Glasgow coma scale.

STATA version 14 for Windows was used to perform statistical analyses, where statistical significance was defined as $p < 0.05$. The significance level for the post hoc tests was adjusted ($p < 0.01$) to control for type I error. Approval for this study was obtained from the Institutional Review Board of the Medical Sciences Campus of the University of Puerto Rico.

3. Results

A total of 2,093 patients with pedestrian injuries was admitted to the hospital during the study period, of which 76.6% were males. Most pedestrians were between the ages of 35 and 64, with the highest relative frequency in the 45–54 age group (17.3%). The distribution of sex across the age groups was statistically different ($p < 0.001$). The frequency of men among injured pedestrians tended to be higher in young adults than in older people. Eighty-three percent (82.6%) of patients among 25–34 years of age were males vs. 70.3% in the 65–74 age category ($p = 0.002$) or vs. 70.6% in the 75–84 age group ($p = 0.005$).

Furthermore, the majority of pedestrian injuries occurred between the 8pm and 4am (44.7%). However, partial testing showed that patients younger than 16 years of age (35.9%) suffered injuries between the 8pm and 12am with more frequency than patients in the 35–44 (19.5%; $p < 0.001$) or 75–84 (19.6%; $p = 0.001$) age groups. In contrast, from 5pm to 8pm pedestrian injuries occurred more commonly among subjects between 75 and 84 years of age (24.8%) than among those in the 25–34 (10.9%; $p < 0.001$) or 16–24 (6.0%; $p < 0.001$) age groups. The youngest patients and the elderly tended to sustain injuries during the weekdays more frequently than young adults. Sixty-seven percent (66.7%) of patients aged 65–74 years and 63.4% of those between 75 and 84 years of age were injured during weekdays compared to 49.6% among those aged 25–34 years ($p < 0.001$) and 48.3% in the16–24 age group ($p = .005$), respectively. As for alcohol use, the largest proportion was observed in subjects between 55 and 64 years of age, with 18.0% (see Table 1).

The frequency of the severe-critical injury severity score (≥25) was higher in elderly patients compared to the youngest age group. Twenty-six percent (26.2%) of pedestrians younger than 16 years of age had an injury severity score ≥25 vs. 45.1% of those aged 65–74 years ($p < 0.001$) and 48.6% of those in the >84 age group ($p = 0.007$). The distribution of severe Glasgow coma scale (<9) also differed across the age groups ($p = 0.042$). Patients in the age range 25–34 (27.5%; $p = 0.004$) and 35–44 (27.6%; $p = 0.003$) had a greater proportion of Glasgow coma scale <9 than their counterparts in the 75–84 age group (14.5%).

In terms of the stay at the hospital, the longest median hospital length of stay was reported in subjects aged 45–54 years (Med.: 15, IQR: 27), which length of stay significantly differed from those of the subjects in younger age ranges: <16 years (Med.: 8, IQR: 12; $p < 0.001$), 16–24 years (Med.:

10, IQR: 15; $p < 0.001$), and 25–34 years (Med.: 10, IQR: 20; $p = 0.009$). The median trauma intensive care unit length of stay was significantly longer among pedestrians in the age range 55–64 (Med.: 19, IQR: 14; $p = 0.002$) and 65–74 (Med.: 22.5, IQR: 21.5; $p < 0.001$) than among pedestrians aged 16–24 years (Med.: 12.5, IQR: 17). As to mortality, older patients exhibited higher death rates than the younger age groups: <16 years (5.5%) vs. 65–74 years (29.2%; $p < 0.001$); 16–24 years (12.9%) vs. 75–84 years (34.0%; $p < 0.001$); and 25–34 years (15.5%) vs. >84 years (45.7%; $p < 0.001$). Patient and injury characteristics by age categories are depicted in Table 1.

Table 2 describes the distribution of specific pedestrian injury types in each age group. Lower extremity fractures (46.6%) were the most common form of trauma, followed by intracranial injuries (35.5%) in all age groups, except the youngest group (<16 years of age). Children younger than 16 showed the opposite pattern: first were intracranial injuries (34.6%), then lower extremity fractures (33.6%). However, when comparing the age groups, older patients had a greater proportion of upper extremity fractures than their younger counterparts: <16 years (15.2%) vs. 65–74 years (31.1%; $p < 0.001$) and 16–24 years (16.9%) vs. 75–84 years (32.7%; $p = 0.001$). Moreover, lower extremity fractures were less common in pedestrians younger than 16 years of age (33.6%) compared to adults, such as those aged 55–64 years (51.3%; $p < 0.001$) and those aged 65–74 years (49.3%; $p = 0.001$).

In terms of trauma to the chest, elderly patients exhibited greater proportions of rib, sternum, larynx, and trachea fractures compared to their younger counterparts: <16 years (6.9%) vs. 65–74 years (34.3%; $p < 0.001$) and 16–24 years (7.5%) vs. 75–84 years (30.7%; $p < 0.001$). In contrast, regarding abdominal and pelvic injuries, pedestrians younger than 16 years of age (13.4%) suffered hepatic injuries more commonly than older pedestrians, such as those in the age range 55–64 (5.8%; $p = 0.003$) and 65–74 (5.5%; $p = 0.005$). Furthermore, subjects in the 16–24 age group (13.9%) sustained more splenic injuries than subjects in the age range 65–74 (4.6%; $p = 0.001$) and 75–84 (3.3%; $p = 0.001$).

Table 3 describes multivariate analyses, all of which were adjusted for sex, injury severity score, and Glasgow coma scale. Pedestrians in the 65–74 age group stayed at the trauma intensive care unit four times ($RR = 4.08$; 95%CI: 2.79, 5.97) longer than their youngest counterpart. Meanwhile, patients in the age range 75–84 stayed three times ($RR = 3.16$; 95%CI: 2.03, 4.90) longer at the trauma intensive care unit compared to the reference group. These patients (75–84 years of age) also spent more days at the hospital ($RR = 2.09$; 95%CI: 1.67, 2.61) than patients younger than 16 years of age. When assessing mortality, it was noted a dose-response effect. Compared with the youngest age group, the risk of death was increased 6.6-fold (95%CI: 2.84, 15.27) in pedestrians aged 35–44 years, 14-fold (95%CI: 5.90, 33.18) in those aged 65–74 years, and 24.6-fold (95%CI: 8.10, 74.41) in those older than 84 years of age.

4. Discussion

This study shows the distribution of pedestrian injuries by age categories, providing further insight about their impact on the morbidity and mortality of this population. The bulk of injured pedestrians in the study were males, concurring with similar studies (Ballesteros et al., 2004; Siram et al., 2011; Small et al., 2006; Starnes et al., 2011). These patients were mostly between the ages of 35–64. Some studies reported that adults were the most injured pedestrians, defining "adults" as people within the ages of 15 to late fifties and early sixties (Peng & Bongard, 1999; Starnes et al., 2011). These broadly defined age categories could distort the significance of age in sustaining pedestrian injuries (Peng & Bongard, 1999; Starnes et al., 2011). The use of nine age groups in our study aimed to reduce this setback. Our results suggest that people between the ages of 35 and 64, especially men, are more susceptible to sustain pedestrian injuries, possibly due to their proximity to busy traffic in urban areas in Puerto Rico.

As for the time in which the pedestrian injuries occurred, most of them happened between 8pm and 4am, hours where visibility is significantly reduced. A recent report on Puerto Rico pedestrian

Table 2. Comparison of specific pedestrian injury type by age categories

Age (years)	ICD 9	< 16 n (%)	16–24 n (%)	25–34 n (%)	35–44 n (%)	45–54 n (%)	55–64 n (%)	65–74 n (%)	75–84 n (%)	>84 n (%)	All ages n = 2,093	*p*
Characteristic												
External Injuries:												
Superficial Injury	910–919	11 (5.07)	4 (1.99)	2 (0.78)	11 (3.24)	5 (1.38)	3 (0.97)	1 (0.46)	0	0	37 (1.7)	0.001
Contusion of upper extremity	920–924	10 (4.61)	10 (4.98)	6 (2.33)	14 (4.12)	14 (3.87)	17 (5.52)	6 (2.74)	8 (5.23)	1 (2.86)	86 (4.11)	0.661
Open wound of lower extremity	890–894	10 (4.61)	12 (5.97)	14 (5.43)	22 (6.47)	14 (3.87)	17 (5.52)	9 (4.11)	5 (3.27)	1 (2.86)	104(4.97)	0.762
Open wound of upper extremity	880–884	0	4 (1.99)	10 (3.88)	10 (2.94)	12 (3.31)	4 (1.30)	11 (5.02)	5 (3.27)	1 (2.86)	57 (2.72)	0.055
Open wound of head/neck/trunk	870–879	24 (11.06)	15 (7.46)	28 (10.85)	32 (9.41)	31 (8.56)	33 (10.71)	19 (8.68)	15 (9.80)	2 (5.71)	199 (9.51)	0.874
Extremities:												
Upper extremity fracture	810–819	33 (15.21)	34 (16.92)	54 (20.93)	75 (22.06)	103 (28.45)	83 (26.95)	68 (31.05)	50 (32.68)	6 (17.14)	506 (24.18)	<0.001
Lower extremity fracture	820–828	73 (33.64)	94 (46.77)	119 (46.12)	164 (48.24)	175 (48.34)	158 (51.30)	108 (49.32)	67 (43.79)	17 (28.57)	975 (46.58)	0.013
Lower extremity sprain	843–845	0	0	3 (1.16)	1 (0.29)	3 (0.83)	1 (0.32)	1 (0.46)	0	0	9 (0.43)	0.491
Head:												
Intracranial Injury	850–854	75 (34.56)	77 (38.31)	90 (34.88)	118 (34.71)	128 (35.36)	103 (33.44)	85 (38.81)	54 (35.29)	12 (34.29)	742 (35.45)	0.959
Skull fracture	800–802	49 (22.58)	42 (20.90)	48 (18.60)	70 (20.59)	75 (20.72)	53 (17.21)	39 (17.81)	25 (16.34)	8 (22.86)	409 (19.54)	0.764
Chest:												
Heart and lung injury	861	43 (19.82)	37 (18.41)	51 (19.77)	72 (21.18)	84 (23.20)	82 (26.62)	65 (29.68)	38 (24.84)	10 (28.57)	482 (23.03)	0.070
Pneumothorax/hemothorax	860	26 (11.98)	20 (9.95)	29 (11.24)	44 (12.94)	43 (11.88)	41 (13.31)	30 (13.70)	8 (5.23)	7 (20.00)	248 (11.85)	0.192
Rib, sternum, larynx, trachea fracture	807	15 (6.91)	15 (7.46)	47 (18.22)	78 (22.94)	97 (26.80)	87 (28.25)	75 (34.25)	47 (30.72)	8 (22.86)	469 (22.41)	<0.001
Abdomen, pelvis:												
Hepatic injury	864	29 (13.36)	20 (9.95)	18 (6.98)	27 (7.94)	26 (7.18)	18 (5.84)	12 (5.48)	7 (4.58)	2 (5.71)	159 (7.60)	0.029
Splenic injury	865	12 (5.53)	28 (13.93)	32 (12.40)	40 (11.76)	27 (7.46)	17 (5.52)	10 (4.57)	5 (3.27)	0	171 (8.17)	<0.001
Genitourinary injury	866–867	8 (3.69)	17 (8.46)	21 (8.14)	23 (6.76)	24 (6.63)	17 (5.52)	12 (5.48)	12 (7.84)	0	134 (6.40)	0.332
Retroperitoneal, peritoneal and extra-hepatic biliary injury	868	2 (0.92)	3 (1.49)	10 (3.88)	8 (2.35)	12 (3.31)	17 (5.52)	6 (2.74)	7 (4.58)	0	65 (3.11)	0.066
Gastrointestinal tract injury	863	6 (2.76)	6 (2.99)	13 (5.04)	20 (5.88)	18 (4.97)	8 (2.60)	7 (3.20)	7 (4.58)	2 (5.71)	87 (4.16)	0.427
Pelvic fracture	808	2 (0.92)	3 (1.49)	10 (3.88)	8 (2.35)	12 (3.31)	17 (5.52)	6 (2.74)	7 (4.58)	0	65 (3.11)	0.066

Table 3. Multivariate analysis of study outcomes according to age categories

Age (years)	Mortality OR (95%CI)	TICU LOS (days) RR (95%CI)	LOS (days) RR (95%CI)
< 16	Ref.	Ref.	Ref.
16–24	3.57 (1.44, 8.85)	1.54 (1.01, 2.31)	1.07 (0.87, 1.33)
25–34	3.86 (1.60, 9.30)	2.71 (1.87, 3.94)	1.38 (1.13, 1.68)
35–44	6.59 (2.84, 15.27)	2.15 (1.55, 3.00)	1.54 (1.27, 1.86)
45–54	4.16 (1.78, 9.73)	2.67 (1.91, 3.73)	1.82 (1.51, 2.19)
55–64	9.42 (4.07, 21.82)	2.83 (2.03, 3.94)	1.78 (1.47, 2.15)
65–74	14.00 (5.90, 33.18)	4.08 (2.79, 5.97)	1.84 (1.50, 2.27)
75–84	20.03 (8.31, 48.30)	3.16 (2.03, 4.90)	2.09 (1.67, 2.61)
>84	24.55 (8.10, 74.41)	1.61 (0.68, 3.82)	1.59 (1.10, 2.30)

*All models were adjusted for sex, ISS, and GCS. TICU: trauma intensive care unit; LOS: length of stay; OR: odds ratio; RR: relative risk; CI: confidence interval; Ref: reference category.

fatalities highlighted some urban planning mistakes that could have contributed to increase the risk of this type of accidents, such as improper sidewalk length, faulty pedestrian traffic signals and pushbuttons, and poor road lighting (Colcucci Ríos, 2014). This implies that there is a possible correlation between the incidence of pedestrian injuries and road visibility and infrastructure.

Our findings show that alcohol might be a contributing factor to pedestrian injuries, as a considerable proportion of males between the ages of 25 and 84 were under the influence of alcohol when they sustained their injuries. Alcohol consumption could have led to impaired judgment and motor coordination, further increasing the risk of suffering motor vehicle collision induced pedestrian injuries (Ballesteros et al., 2004; Small et al., 2006; Törő et al., 2005).

The most common injuries were lower extremity fractures, followed by intracranial injuries, except in the youngest children where the opposite pattern was observed. The former result is consistent with previous studies by Siram et al. (2011) and Peng and Bongard (1999), but contrasts with other pedestrian trauma reports, which show head injuries to be the most prevalent trauma type (Harruff et al., 1998; Li et al., 2015; Small et al., 2006; Törő et al., 2005; Vestrup & Reid, 1989). These injury distributions may be explained by the recorded pattern of initial forceful impact between the pedestrian's lower extremities and the vehicle, followed by head impact on the vehicle windshield or ground (Peng & Bongard, 1999).

The variations observed in the types of pedestrian trauma by age, such as hepatic injuries seen in younger age groups or chest injuries and upper extremity fractures in the older age groups, suggest that age -a proxy for height and stature- may predispose people to suffer specific pedestrian injuries. According to Peng and Bongard (1999), adults, who are usually taller, are more likely to receive upper body injuries, whereas children's short stature puts them at risk of receiving head injuries. This pattern of injury seen in adults is consistent with our study findings, but we did not observe a statistically significant difference in head injuries between all the age groups. Nevertheless, intracranial injuries were the most frequent mechanism of trauma in younger children. As Siram et al. (2011) discussed in their study, elderly pedestrians seem to have a higher risk of sustaining bony injuries, such as, lower and upper extremity fractures, probably due to physiological changes associated with aging, such as osteoporosis, muscle dystrophy, and decreased subcutaneous tissue. Physiological changes associated with age may contribute to the injury patterns observed in the Puerto Rican pedestrian population.

Our findings showed a higher prevalence in severe injury severity score and mortality as age increases, similar to other studies (CDC, 2015; Ballesteros et al., 2004; Siram et al., 2011; Small et al., 2006; Vestrup & Reid, 1989). In a comparable research study, elderly patients were reported to be six to eight times more likely to die compared to their younger counterparts, whereas our study showed an alarming 14-fold increase risk in mortality for the 65–74 age group (Siram et al., 2011). These findings, along with those of other publications, indicate that elderly people have the highest risk of receiving fatal pedestrian injuries (Ballesteros et al., 2004; Centers for Disease Control and Prevention, 2015; Siram et al., 2011; Small et al., 2006; Vestrup & Reid, 1989).

A similar pattern was observed with longer trauma intensive care unit length of stay and hospital length of stay in all age groups except for the oldest, which showed no significant difference compared to the reference group (<16 years old). The linear dose-response relationship between age and mortality risk demonstrated in our study may explain why we observed a shorter trauma intensive care unit length of stay and hospital length of stay in the oldest age group. The weakened physical condition and preexisting diseases of elderly people may put them in a disadvantaged position to recover from their injuries, which is reflected in their higher mortality rates and shorter hospital stays (Lane et al., 1994; Sklar et al., 1989).

Although we were able to describe pedestrian injury morbidity and mortality patterns in nine age categories, our study was presented with some limitations. The PRTH receives most if not all patients sustaining traumatic injuries, but we might not receive all minor injuries and out-of-hospital fatalities, limiting our population size. Another encountered limitation was the lack of detailed information about pedestrian vs. motor-vehicle accidents, such as collision speeds, vehicle type, and vehicle impact location, which could have provided further evidence of the effects these variables have on the mortality rates of injured pedestrians. Several studies have reported that high-speed vehicle collisions increase the risk of having severe injury severity score and high mortality rates in injured pedestrians (Aleassa, Eid, & Abu-Zidan, 2013; Ballesteros et al., 2004; Damsere-Derry, Ebel, Mock, Afukkar, & Donkor, 2010; Li et al., 2015; Rosén, Stigson, & Sander, 2011. The association between pedestrian injury/fatality and collision speed denotes that one of the best measures to reduce this risk is to enforce harsher road safety regulations that lower speed limits in heavily populated areas. Furthermore, injury site information on road, illumination and crosswalk conditions were not available in the Trauma Registry of the hospital, which may have allowed us to evaluate the external factors influencing pedestrian injuries. Moreover, the lack of complete information of alcohol consumption in our patients (57% missing values) limited our analysis on the possible relationship between alcohol and pedestrian morbidity and mortality. On the other hand, the key strength of this analysis is that it provides the necessary evaluation of pedestrian injuries by age categories in Puerto Rico and establishes a basis of comparison with other populations.

5. Conclusion

According to our findings, most pedestrian injuries were sustained by males and varied with age. The most common injury in all age groups were lower extremity fracture, followed by intracranial injuries, except for the youngest group. Intracranial injuries were the most common injury type in children younger than 16, whereas people between the ages of 35 and 84 had a higher incidence of chest injuries than other age groups. In regard to mortality, patients aged 65–74 years and older than 84 had a 14-fold and 24.6-fold increase risk of dying from pedestrian injuries, respectively, compared to the youngest group. The differences in injury types and mortality could be attributed to the physiological characteristics associated with aging.

To diminish the incidence of pedestrian injuries, preventive measures must be tailored to the needs of each age group. These interventions should employ an intersectional approach considering road traffic legislation regarding pedestrian safety, educational programs in schools or town halls that delineate the responsibilities of drivers and pedestrians, and better urban planning, such as road, illumination and crosswalk condition quality control, to reduce the contribution of external factors on this public health threat. Further investigation about the influence of extrinsic factors, such as road and traffic maintenance and illumination and vehicle collision speed, on pedestrian injuries may help develop and refine management strategies.

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