Factors Affecting the Severity of Pedestrian Traffic Crashes

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Abstract

Background: Considering the importance of pedestrian traffic crashes and the role of environmental and demographic factors in the severity of these crashes, this article aimed to review the published evidence and synthesize the results of related studies to determine any associations between demographic and environmental factors and the severity of pedestrian-vehicle crashes. **Methods:** All epidemiological studies published from 1970 to 2019 were searched in international electronic databases (PubMed [Medline], Scopus, Web of Science, Embase, ScienceDirect, and Ovid) and reference lists of the identified articles were also searched. Studies were included if they investigated the severity of pedestrian-vehicle crashes as outcome, measured any environmental and demographic factors for pedestrian-vehicular crashes as exposure, designed observational, and if they were written in all languages. Quality of included studies was evaluated using the strengthening the reporting of observational studies in epidemiology checklist for observational studies. **Results:** We found 3126 references among which 24 studies were included in this review. All retrieved studies were conducted between 1990 and 2019 and had a cross-sectional design. In most of these studies, the associations between environmental and demographic variables such as vehicle speed or speed limits, pedestrian age, lighting, type of road, type of vehicle, and alcohol intake with the severity of pedestrian traffic crashes were examined. **Conclusion:** This study showed that few studies were conducted in this area; in fact, most of the studies were carried out in metropolises of developed countries. As a result, studies which provide strong causal inferences by focusing on high-risk groups and a higher level of evidence such as cohort and case-control ones are needed in developing countries.

Keywords: Pedestrian, review, severity of traffic crash

Introduction

Deaths and injuries of pedestrians caused by traffic crashes have been growing in recent years in the world.[1] Globally, pedestrians constituted 22% of those killed on the world's roads. Each year, about 270,000 pedestrians lost their lives due to traffic crashes.[2] Pedestrians also accounted for the

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highest rate of traffic fatalities in the world's most populated cities. For example, in the cities of Mumbai and New Delhi, deaths of pedestrians constituted 78% and 53% of the traffic fatalities, respectively.[3]

Moreover, world statistics showed that there was a difference in the ratio of pedestrian deaths to the whole traffic fatalities in different countries. This proportion is much higher in developing countries than in developed ones. For example, 86% and 68% of traffic deaths were because of pedestrian traffic crashes in Peru and Mozambique, respectively, while they were 13% and 26% for the United States of America and Canada, respectively.[4,5]

In addition, injuries in pedestrian – vehicle crashes were usually more severe in low- and middle-income countries than in developed ones. However, the proportion of deaths and injuries and the number of cars did not fit. For example, 80% of the cars are in North America, Western Europe, and Japan which only included 15% of the population, whereas 85% of traffic deaths and 90% of disabilities resulting from pedestrian traffic crashes occurred in low- and middle-income countries.[6-10]

Furthermore, a significant number of victims in traffic crashes were child and teenager pedestrians. According to the World Health Organization (WHO), approximately 21% of traffic crash fatalities were related to child pedestrians, and about 720 child pedestrians lost their lives daily in road crashes.[11]

Given the importance of this issue and lack of a review on existing relevant studies to determine the role of demographic and environmental factors in the severity of pedestrian-vehicle traffic crashes, this review aimed to find, evaluate, and synthesize the results of relevant studies to determine environmental and demographic factors, which were associated with the severity of pedestrian-vehicle crashes.

Objectives

This article aimed to review the published evidence and synthesize the results of related studies to determine any associations between demographic and environmental factors and the severity of pedestrian-vehicle crashes.

Methods

This study sought to identify all observational studies which investigated the association between environmental and demographic factors and the severity of pedestrian-vehicle crashes from 1970 to 2019. The question addressed in this review was: which environmental and demographic factors were significantly associated with severity of pedestrian-vehicle crashes as an outcome?

PubMed (Medline), Scopus, Web of Science, Embase, ScienceDirect, and Ovid databases were searched for published articles and reports. Reference lists of identified articles and proceedings of relevant conferences were also hand-searched. The search was done as follows: (pedestrian) AND (crashes OR vehicle collisions OR injury OR casualties OR hazard OR risk factor OR safety OR security OR environmental attributes OR demographic attributes OR environmental characteristics OR built environment OR vehicle speed OR road segments OR traffic OR transportation OR alcohol intake).

In fact, studies were included if they investigated the severity of pedestrian-vehicle crashes as outcome, measured any environmental and demographic factors for pedestrian-vehicular crashes as exposure, designed observational, and if they were written in all languages. Moreover, assessment of the quality of the studies was done as follows: Published articles in indexed and peer review journals were considered to be the indication for the quality of these articles. In addition, quality of articles published in nonindexed journals, reports, and books published by UN agencies (WHO, UNESCO, UNICEF) and the World Bank, and the proceedings of conferences and seminars were assessed by experts in epidemiology and traffic crashes using the strengthening the reporting of observational studies in epidemiology checklist.

In fact, titles and abstracts of the studies were reviewed by two separate Ph. D. candidates of Epidemiology. Articles and reports that were deemed irrelevant by these two reviewers were excluded from the study list. The number of excluded articles and their titles were recorded. Then, the full text of articles and reports were retrieved and referred to two independent teams of reviewers. Each team separately extracted the answers to the research question from the contents of the paper and took the necessary notes. In case of any discrepancy, the original text of the article was evaluated by the project supervisor and decisions were made.

Results

The reviewers scanned 3126 studies; 3088 titles were irrelevant to the objectives of this review and they were excluded from the study. Full texts of the remaining 38 studies were retrieved and screened, among which, 24 studies met the inclusion criteria. Figure 1 shows the selection process of enrolled studies. All retrieved studies were conducted from 1990 to 2019 and used a cross-sectional design. Characteristics of the studies, including the country, study population, data source, sample size, study period, main results, and the statistical model used in the study, are summarized in Table 1.

The results of the studies which investigated the associations between demographic and environmental variables (independent variables) such as vehicle speed/speed limit, pedestrian age, lighting (light condition), types of road, alcohol intake, and vehicle type with the severity of traffic crashes (dependent variable) were as follows:

Vehicle speed or speed limit

In 14 of the 24 reviewed studies, the associations between the severity of pedestrian-related traffic crashes and vehicle speed or speed limit were statistically significant.[12,14,15,17-19,21-23,25-28,34] These studies used various indicators including speed limit, vehicle speed, speeding, impact speed, unsafe speed and speed. The speed was measured in miles per hour (mph) in a number of studies and kilometers per hour (km/h) in the others. The significance level ranged from $P < 0.05$ to

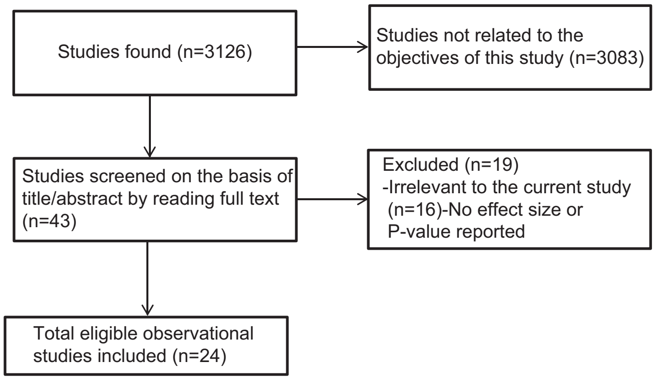

Figure 1: Selection process of the studies

$P < 0.00001$. In a study conducted by Mohamed *et al*., the significance level was $P < 0.00001$ which was higher than that in other studies. In this study, the statistical population was the total population, and pedestrian death was used as an outcome variable.[23] The correlation was positive in the majority of studies. In other words, studies showed that with the increase of vehicle speed or speed limit, the severity of pedestrian crashes also increased.

Pedestrian age

In 16 out of the 24 studies, the associations between the severity of pedestrian crashes and pedestrian age were statistically significant.[13,15,17-20,22,23,26,27,33] In all 10 studies, by increasing the age of pedestrians, the severity of pedestrian traffic crashes also increased and hence that, the severity of injuries was reported to be higher in the elderly people over 60 years old. The significance level ranged from $P < 0.05$ to $P < 0.000001$. The significance level, in the study of Zajac and Ivan, was higher than that in other studies ($P < 0.000001$). In this study, the statistical population was the total population, and the severity of injury was used as an outcome variable.[13]

Light condition

In 13 out of 24 studies, the associations between the severity of pedestrian crashes and lighting were statistically significant.[14,15,18,20-24,26-30] These studies used various indicators including lighting, daylight, and light conditions. The significance level ranged from $P < 0.05$ to $P < 0.0001$. In a study conducted by Mohamed *et al*., the significance level was reported to be higher than that in other studies ($P < 0.0001$). In this study, the statistical population was the total population, and pedestrian death was used as an outcome variable.[23] The correlation was positive in the majority of the studies. In other words, these studies demonstrated that when darkness increased (with light decreasing), the severity of pedestrian crashes also increased.

Type of road

Twelve of 24 reviewed studies showed statistically significant associations between the severity of pedestrian crashes and type of the road.[5,17,19,21,23,25-27,29,30,32] In most of these studies, the number of traffic lanes in the carriageway was used to divide roads in the area, and in few studies, roads were divided into national and state, urban and rural or main, and side roads. The significance level ranged from $P < 0.05$ to $P < 0.001$. In the study of Zhao *et al*., the significance level was higher than that in other studies ($P < 0.001$). In this study, the statistical population was over 18 years, and the pedestrian death was used as an outcome variable.[25]

Alcohol intake

In 10 of 24 studies, the associations between the severity of pedestrian crashes and alcohol intake by drivers or pedestrians were statistically significant.[13-15,19-23,26,34] All of these studies showed that when alcohol intake level increased, the severity of pedestrian crashes also increased. The significance level ranged from $P < 0.05$ to $P < 0.0001$. In studies by Zhang *et al*., MacLeod *et al*., and Mohamed *et al*., the significance level was higher than that in other studies ($P < 0.0001$).[22,23,26] The statistical population in all three studies was the total population, and pedestrian death was used as an outcome variable.

Type of vehicle

In this study, 12 of the 24 studies showed that there was a significant association between the severity of pedestrian crashes and type of vehicle.[13,14,20,21,23,24,26-30,32] In these studies, the severity of pedestrian injuries caused by heavy vehicles crashes such as trucks and buses was compared to those caused by light-motor vehicles. These studies showed that in heavy vehicle-related crashes, severity of pedestrian injuries was much higher. The significance level ranged from $P < 0.01$ to $P < 0.05$. In studies by Zhang *et al*., the significance level was higher than that in other studies ($P < 0.01$). The statistical population was the total population, and the pedestrian fatality and serious injury were used as outcome variables.[26]

There was also a significant association between variables such as time of day, weather, traffic control, pedestrian action (crossing roads or junctions), location of pedestrian crossing, commercial and industrial land use, population density, mixed-use (this word is often used to indicate a mix of housing types, for example, detached houses and apartments.[35]) pedestrian sex, pedestrian clothing, weekday, driver sex, driver job, average income, season, traffic attributes in terms of presence of signal control, number of road lanes, driver skills, transit access, and pedestrian negligence with the severity of pedestrian-related crashes in, at least, one of the reviewed studies.

Discussion

This review article summarized the results of related studies conducted worldwide to assess the role of demographic and environmental factors in the severity of pedestrian-vehicular traffic crashes. In the reviewed studies, a relatively wide range of demographic and environmental factors affecting the severity of pedestrian crashes was investigated. Most of these studies were carried out in the United States and in most cases, the binary or multinomial logistic regression and ordered probit models were used to measure the association between dependent and independent variables. Furthermore, in most studies, the statistical population consisted of the total population of the area, and in a number of studies, the statistical

Table 1: Characteristics of studies included in the review

Authors (year) (reference)	Country	Study population	Data source	Sample size	Study period	Statistical model	Injury severity scale	Outcome
Pitt *et al*., 1990[12]	USA	Youth <20 years of age	Highway Traffic Safety Administration (NHTSA)	1035	1977-1980	Logistic regression model	ISS	Vehicle travel (speed>30 mph), residential zone, type of road (including collectors and major roads), pedestrian age (<5 years), time of day (either early morning or late afternoon), and center travel lanes increases severity of injury. In contrast, using different maneuvers to avoid the crash reduces injury severity
Zajac and Ivan 2003[13]	USA	Total population	CDOT	264	1989-1998	Ordered probit model	KABCO scale	Vehicle type, driver and pedestrian alcohol involvement, pedestrian age 65 years or older and clear roadway width are significantly related to the severity of injury
Lee and Abdel-Aty 2005[14]	USA	Total population	Florida Department of Highway Safety and Motor Vehicles	7000	1999-2002	Ordered probit model	No injury, Possible injury, Nonincapacitating evident injury, Incapacitating injury, and Fatal injury	Pedestrians' alcohol/drug use, vehicle high speed, vehicle type (larger than passenger cars), adverse weather, dark lighting, and no traffic control indicate a statistically significant association with injury severity
Sciortino *et al*., 2005[15]	USA	Total population	SWITRS and records of pedestrians treated at SFGH	1323	2000-2001	Logistic regression model	ISS	Driver movement (straight, turning right or left), driver speeding, driving under influence, pedestrian age (>65), and lighting condition (dark) increase the severity of injury
Clifton and Kreamer-Fults 2007[16]	USA	Total population	State of Maryland Motor Vehicle Accident Reports	1513	2000-2002	OLS linear regression	KABCO scale	Variables such as school characteristic (recreation), area characteristics (commercial access, transit access), race, population density, and mixed use indicate a statistically significant association with injury severity
Sze and Wong 2007[17]	China	Total population	TRADS	73,746	1991-2004	Logistic regression	Killed or severe injury, Slight injury	Pedestrian age (under 15 and above the age of 65 years), pedestrian action (crossing road or junction), speed limit (over 50 km/h), obstruction (at or near obstruction), road type (multi-/dual carriageway), and environmental contributory (pedestrian negligence) indicate a statistically significant relation with injury severity

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Authors (year) (reference)	Country	Study population	Data source	Sample size	Study period	Statistical model	Injury severity scale	Outcome
Eluru *et al*., 2008[18]	USA	Total population	GES database	2944	2004	MGORL model	No injury, nonincapacitating injury, incapacitating injury, fatal injury	Most important variables influencing nonmotorist injury severity are the age of the individual (bicyclists over 60 years), injury location (head injury), accidents on high-speed roads (>50 mph), pedestrian location (on the crossing, within 15 m of crossing), pedestrian action (crossing road/junction), special circumstance (overcrowded footpath), traffic congestion (severe), junction control (not at junction), road type (two-way carriageway, multi-/dual carriageway), and time-of-day (7:00-9:59 a.m. 7:00 p.m. 6:59 a.m. 10:00 a.m.-3:59 p.m.)
Kim *et al*., 2008[19]	USA	>18 years	Police-reported pedestrian-vehicle crashes from the State of North Carolina	5808	1997-2000	Heteroskedastic model	Fatal injury, incapacitating injury, nonincapacitating injury	Increasing pedestrian age, sex (male driver), darkness with or without streetlights (2-4 times greater probability of mortality), intoxicated driver (2.7 times greater probability of mortality), commercial area, sport-utility vehicle, truck, freeway, two-way divided roadway, speeding-involved, off roadway, motorist turning or backing, both driver and pedestrian at fault, and pedestrian only at fault indicate statistically significant association with injury severity
Clifton *et al*., 2009[20]	USA	Total population	Maryland motor vehicle accident report	4500	2000-2004	Generalized ordered probit model	No injury, nonfatal injury, fatality	Pedestrians who are not in a crosswalk, cross against the traffic signal, and are experienced a crash after dark are associated with a greater injury risk Regarding built environment, policy variables of interest, transit access and greater pedestrian connectivity, like central city areas are negatively related with the severity of injury

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Authors (year) (reference)	Country	Study population	Data source	Sample size	Study period	Statistical model	Injury severity scale	Outcome
Kim *et al*., 2010[21]	USA	>18 years	Police-reported pedestrian-vehicle crashes from the State of North Carolina	5808	1997-2000	Mixed logit model	Fatal injury, incapacitating injury, nonincapacitating injury, possible/no injury	Darkness without streetlights, vehicle as truck, freeway, speeding involved, and collisions involving a motorist who had been drinking increase fatality probability for pedestrians in motor-vehicle crashes as 400%, 370%, 330%, 360%, and 250%, respectively
MacLeod *et al*., 2012[22]	USA	Total population	FARS	34,940	1998-2007	Logistic regression model	Fatality, nonfatality	Time of day (midnight-7.59 am, 8:00-11:59 pm), week day (weekend), light conditions (some light to dark), speed limit (>55 mph), pedestrian age (<25 and>60), location (road), driver age (≤25), driver sex (male), alcohol use (≥10), prior suspensions, invalid license, vehicle older than 5 years indicate a statistically significant relation with fatal accidents
Rothman *et al*., 2012[5]	Canada	Total population	Motor Vehicle Collision Reports filed by the Toronto Police Service	9575	2000-2009	Binary and multinomial logistic regression models	No injury, minor injury, major injury, fatal injury, severe injury (major + fatal)	Uncontrolled mid-block crossings and major arterial roadways show a statistically significant association with severe accidents
Mohamed *et al*., 2013[23]	Canada and USA	Total population	Quebec's auto insurance company (SAAQ) and NYCDOT	5820 and 6896	2033-2006 2002-2006	Multinomial logit model and Ordered probit model	Fatal crash, minor injury	Location (accident at intersection), type of vehicle movement at accident (straight), environmental condition (after dark), median income, transit access and mixed-use (HHI/1000) indicate statistically significant association with fatal accidents
Aziz *et al*., 2013[24]	USA	Total population	NYSDOT	7354	2002-2006	Random parameter logit model	Severe injury, fatality	Road characteristics (number of lanes, grade, light condition, road surface), traffic attributes (presence of signal control), type of vehicle, and land use (parking facilities, commercial and industrial land use) indicate a statistically significant association with the severity of accident

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Table 1: Contd...

Authors (year) (reference)	Country	Study population	Data source	Sample size	Study period	Statistical model	Injury severity scale	Outcome
Zhao *et al.*, 2014[25]	China	>18 years	Institute of Surgery, Third Military Medical University, Chongqing	121	2006-2011	Logistic regression model	Fatality, nonfatality	Road type (urban road) and vehicle impact speed (>70) indicate statistically significant relation with severe collision accidents
Zhang *et al.*, 2014[26]	China	Total population	Ministry of Public Security of Guangdong Province	6967	2006-2010	Logistic regression model	Killed or serious injured and disappearance Minor or no injury	Pedestrian's fault, drunk driving, speeding, pedestrian's age (45-69), driver's gender (male), driving experience (0-2 years), driver's job (workers and migrant workers), vehicle unsafe status (unfit safety status), commercial vehicle, vehicle type (truck), urban highways, street-light condition (no street-lighting), week day (weekend) and time (0.00-6.59, 17:00-19:59) indicate a statistically significant relation with severe accidents
Sasidharan and Menéndez 2014[27]	Switzerland	Total population	National accident database maintained by the Federal Road Office	12,630	2008-2012	Partial proportional odds model	Fatal injury, severe injury, minor injury, PDO	Winter months, pedestrians crossing at mid-block, intersection, motorbike, heavy vehicle, distraction, national road, flat, weather, darkness, speed and age indicate a statistically significant association with severe accidents
Haleem *et al.*, 2015[28]	United States	Total population	FDOT	7330	2008-2010	Mixed logit model	Fatal, incapacitating injury, nonincapacitating injury, possible injury, and PDO	At signalized intersections higher AADT, speed limit, and percentage of trucks; very old pedestrians; at-fault pedestrians; rainy weather; and dark lighting condition were associated with higher pedestrian severity risk. At unsignalized intersections, pedestrian walking along roadway, middle and very old pedestrians, at-fault pedestrians, vans, dark lighting condition, and higher speed limit were associated with a higher pedestrian severity risk
Pour-Rouholamin and Zhou 2016[29]	United States	Total population	Police-reported roadway crash data in Illinois	19,361	2010-2013	Generalized ordered logit model	KABCO scale	Older pedestrians (>65-years-old), pedestrians not wearing contrasting clothing, adult drivers (16-24), drunk drivers, time of day (20:00-05:00), divided highways, multilane highways, darkness, and heavy vehicle associated with severe injuries

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Table 1: Contd...

Authors (year) (reference)	Country	Study population	Data source	Sample size	Study period	Statistical model	Injury severity scale	Outcome
Kim *et al*., 2017[30]	South Korea	Total population	TAAS	137,470	2011-2013	Hierarchical ordered model	No injury, slight injury, serious injury, and fatal injury	Intoxicated drivers, road-crossing pedestrians, elderly pedestrians, heavy vehicles, wide roads, darkness, and fog. At the municipality level, municipalities with low population density, lower level of financial independence, fewer doctors, and a higher percentage of elderly resident's experience more severe pedestrian crashes
Xin *et al*., 2017[31]	United States	Total population	FDOT	3867	2011-2014	Generalized ordered probability model	Fatal, incapacitating, nonincapacitating, no injury (possible injury or property damage only)	Neighborhood characteristics (African American community, school zone, bus stop area) are found to have significant influence on injury severity in pedestrian-involved crashes
Uddin.and Ahmed 2018[32]	United States	Total population	Highway Safety Information System database	31,84	2009-2013	Ordered probit model	Major injury (fatality and disabling injury), minor injury (evident injury), possible/no injury (possible and no injury)	Pedestrian's age, vehicle type, crash location, day of week, day time, road type indicate a statistically significant association with severe accidents
Moradi *et al*., 2018[33]	Iran	Total population	Traffic police databases	6422	2013	Logistic regression model	Injured or died	Gender, age, pedestrian position and fault, and type of driver's license indicate a statistically significant association with severe accidents
Sun *et al*., 2019[34]	United States	Total population	Pedestrian crash data within statewide	14,236	2006-2015	Multinomial logit model	No injury-injury-fatal/severe	Neither alcohol nor drugs, pedestrian's age, gender, season, day time, weather, and speed limit indicate a statistically significant association with severe accidents

CDOT: Connecticut Department of Transportation, ISS: Injury severity score, SWITRS: Statewide Integrated Traffic Reporting System, SFGH: San Francisco General Hospital, OLS: Ordinary least squares, TRADS: Traffic Accident Database System, GES: General Estimates System, MGORL: Mixed generalized ordered response logit, FARS: Fatality Accident Reporting System, NYCDOT: New York City Department of Transportation, NYSDOT: New York State Department of Transportation, HHI: Herfindahl–Hirschfield index, PDO: Property Damage Only, NHTSA: Highway Traffic Safety Administration, SAAQ: Quebec's auto insurance, company, AADT: Annual Average Daily Traffic, KABCO: K, killed; A, disabling injury; B, evident injury; C, possible injury; O, no apparent injury, FDOT: Florida Department of Transportation, TAAS: Traffic Accident Analysis System

population consisted of people over 18 years old.[19,21,25] Except for the study by Pitt *et al*., in which the study population reported to be people <20 years old.[12]

The results of the reviewed studies showed that the excessive speeding of vehicles, passages with higher speed limits, especially freeways and highways, the darkness of streets, alcohol intake by the drivers or pedestrians, older pedestrians, and heavy vehicles increased the severity of pedestrian crashes.

It is noteworthy that 11, 3, 2, and 1 out of 24 reviewed studies here were conducted in the United States, China, Canada, and Switzerland, respectively. Although various studies showed that most of the pedestrians' injuries and deaths in traffic crashes occurred in developing countries,[2,4,36-38] this study showed that, except for the Chinese studies, none of the reviewed studies was conducted in such countries. Therefore, it is necessary to conduct researches on risk factors affecting the severity of pedestrian-vehicle crashes in developing countries too.

On the other hand, given that most of the studies in this review were conducted in metropolises of developed countries, especially in the United States and Canada, the results cannot be generalized to all urban areas, especially cities with the different demographic and environmental context in low- and middle-income countries.

Moreover, the results showed that most of the reviewed studies were conducted in the metropolitan areas of the United States and Canada, the study area was a city or part of a city, and only inter-urban traffic crashes in the metropolises were investigated. Furthermore, they did not pay attention enough to the severity of crashes and contributing factors in the outer ring and suburban roads, highways, and freeways.

In addition, this review showed that in studies in which the independent variables of population density, land use, and the weather situation were included in the final models, there was a significant association between these variables and the severity of pedestrian crashes as the dependent variable. In order to reduce the severity of injury in pedestrians, it is necessary to implement interventions targeting these factors.

However, only one study investigated the association between household income and the severity of pedestrian crashes.[23] In recent years, most of the studies that investigated the inequity in traffic crashes revealed that the severity of crashes was higher in poor areas.[39-45] Therefore, further studies should be designed to investigate the association between socioeconomic status and the severity of pedestrian-vehicle crashes, especially in metropolises of developing countries to help adopt appropriate strategies to reduce these types of crashes and their consequences.

Furthermore, 12 of 24 studies included in this review revealed a statistically significant association between overspeeding and the severity of pedestrian crashes.[12,14,15,17-19,21-23,25-27] Furthermore, several other studies showed that overspeeding was one of the most important risk factors associated with the increased severity of pedestrian crashes.[21,24,27,46-50] However, they did not pay attention enough to the role of urban and suburban roadway safety facilities in the severity of pedestrian crashes, such as pedestrian bridges, lining of pedestrians crossing and warning signs. In fact, the association of traffic signs and the severity of pedestrian traffic crashes were investigated only in the studies by Eluru, *et al*., Mohamed, *et al*., and Aziz, *et al*.[18,23,24] Considering the fact that these safety facilities are of those environmental factors which can be associated with the severity of pedestrian crashes, it is necessary to include them in the future as well as underway studies.

On the other hand, all studies that met the inclusion criteria of this review were designed as cross-sectional. In fact, lack of studies, especially cohort and case-control methodology, on causal inferences which could provide higher levels of evidence for identifying demographic and environmental risk factors affecting the severity of pedestrian-vehicle crashes was obvious. Therefore, organizations and institutions which are involved in the research and prevention of traffic crashes programs should pay enough attention to these factors, and investigate the risk factors affecting the severity of traffic crashes by conducting studies which provide stronger causal inferences.

Moreover, in most studies (13 of 24), the statistical population was the total population. However, according to the WHO, approximately 21% of deaths of pedestrian traffic crashes occurred in children for which only 1 study, conducted for pedestrians under 18 years old, met the criteria to be included in our study.[11] Because children, especially school-aged children, are one of the most vulnerable groups for such crashes,[51-53] it seems necessary to focus on this group when studying the risk factors associated with the severity of pedestrian traffic crashes.

Finally, no study addressed the role of taxi stations, bus stops, and public parking lots in the severity of pedestrian crashes. Because there is almost a large number of pedestrians in the streets around the bus stops, taxi stations, and public parking lots, the study of the distribution and severity of the pedestrian crashes using the methods such as spatial analysis and regression models can clarify the role of these environmental factors in the severity of pedestrian traffic crashes. Furthermore, the studies showed that the number of bus stops[54,55] and the area of parking lots[16] had an important role in the severity of pedestrian traffic crashes.

Conclusion

The results showed that few studies were conducted on the association between demographic and environmental factors and the severity of pedestrian traffic crashes. Furthermore, the majority of studies were carried out in developed countries, especially in the metropolises of the United States. In these studies, some environmental factors that played an important role in the severity of pedestrian traffic crashes, such as pedestrian safety facilities, were ignored. Strong causal inference schemes were not used, and sufficient attention was not also paid to high-risk groups. Therefore, it is necessary to conduct more research at national and regional levels in cooperation with international organizations which are active in the field of traffic crashes in various parts of the world such as the WHO, especially in developing countries, because a large number of pedestrian crashes occur in these countries. Preventive programs, to reduce the severity of these crashes and their burden, should be developed and implemented in such countries.

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Conflicts of interest

There are no conflicts of interest.

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