International Journal of Sciences

Research Article Volume 2 - October 2013 (10)

Environmental, Human and Socioeconomic Characteristics of Pedestrian Injury and Death in Las Vegas, NV

Jennifer Pharr[1]✎, Courtney Coughenour[1], Timothy Bungum[1]

[1]University of Nevada, Las Vegas; School of Community Health Sciences; Department of Environmental and Occupational Health

Abstract: *Background:* Pedestrian crashes are a deterrent to physical activity, especially walking. The purpose of this study was to analyze pedestrian crash characteristics in Clark County, NV and to determine if there was a significant relationship between pedestrian crashes and socio-economic variables.
Methods: Police reported pedestrian crash data collected between January 2009 and December 2011 were analyzed. Frequencies and rates for pedestrian crashes, injuries and deaths were calculated for environmental and human characteristics. Chi square tests were utilized to determine if there were significant differences in environmental and human characteristics for pedestrian injuries and deaths. Zero-inflated negative binomial (ZINB) regression analysis was utilized to determine if there was a significant relationship between pedestrian crashes and socio-economic variables by urban census tracts.
Results: The majority of pedestrian crashes occurred during the day, when it was clear and the roads were dry. There were significant differences in environmental and human characteristics when pedestrian injuries and deaths were compared. Significant predictors of pedestrian crashes by census tract were percent Hispanic, median age, median household income, and population density.
Conclusions: Because pedestrian crashes are a barrier to physical activity, efforts to reduce them should be undertaken. Solutions could positively impact physical activity and walkability.

Keywords: Pedestrian crashes; environmental characteristics; walkability; built environment; physical activity

Introduction

Research has shown that regular physical activity is important for chronic disease prevention and improvements in overall health and wellbeing. Specifically, habitual physical activity reduces the risks of developing heart disease, stroke, diabetes, high blood pressure and high cholesterol, and has been shown to improve pulmonary function, bone density, and body image [1,2]. As a means to improve health and combat the obesity epidemic in the United States, several national social marketing campaigns (i.e. NFL Play 60 and Let's Move) have been initiated to increase physically active. The U.S. Department of Health and Human Services recommends that children and adolescents engage in 60 minutes (1 hour) or more of physical activity daily. Adults are recommended to complete at least 2.5 hours of moderate-intensity (brisk walk), or 1 hour and 15 minutes of vigorous-intensity (jog) aerobic physical activity weekly [3,4]. Walking is a preferred mode of physical activity because it is accessible to most people [5]. Additionally, efforts to promote walking would prove beneficial; as walking rates do not decline with age like other modes of physical activity [6].

When health is considered from an ecological perspective, we realize that the place (social and physical environment) in which a person lives impacts his/her health [7]. Recent findings have identified characteristics of the environment as important predictors of physical activity [8]. This finding aligns with the social cognitive theory (SCT) which recognizes that the environment is a main contributor to human behavior. Keys to the SCT are the reciprocal relationships between a person, his/her environment and behavior, and that "human behavior is a product of the dynamic interplay of personal, behavioral and environmental influences" [9]. The SCT recognizes that barriers or impediments in the built environment reduce health behaviors, while facilitators increase those behaviors. Specific to physical activity, Evenson and colleagues found that children are more likely to engage in physical activity if the built environment is supportive [10]. Facilitators of physical activity, particularly walking, include well lit streets, walking and biking trails, and sidewalks that are in good repair, while barriers are high-speed and heavy volume traffic, lack of crosswalks or sidewalks, and poorly lit streets [5,10,11].

✎ Jennifer Pharr (Correspondence)
✉ jennifer.pharr@unlv.edu
☎ +

McGinn et al. found a negative association between leisure walking/active transportation and traffic volume, traffic speed, and number of crashes [11]. Pedestrian crashes are a barrier to walking, both for exercise and active transport. If we are to successfully promote walking as a means of physical activity, efforts should be made to ensure a safe walking environment.

For this study, 'pedestrian crashes' refers to the total number of pedestrians injured or killed as a result of being hit by a vehicle. Pedestrian crashes in the United States account for significant morbidity and mortality each year. In 2009 there were over 4,000 pedestrian deaths and 59,000 pedestrian injuries [12]. Naumann et al. note that the United States has fallen behind similar developed nations in reducing the number of pedestrian fatalities [13]. Since the early 1980s, the US has seen a 35% reduction in pedestrian fatalities while similar European countries have experienced reductions in pedestrian fatalities of over 60% [13]. During this same time period, the number of people who walk in the US had decreased while the number of people who walk in European countries has remained high [14].

Pedestrian injury rates within the U.S. have been shown to differ geographically. Paulozzi found that pedestrian fatalities were highest in Sunbelt states (south and southwest) between 1999 and 2003, a time in which the region was experiencing rapid population growth [15]. Based on 2000 census data, Ewing, Schieber, and Zegeer found that urban sprawl was directly linked to pedestrian fatalities, with the most sprawling counties having a fourfold increase in pedestrian fatalities [16]. Within metropolitan areas, pedestrian crashes have been shown to cluster around major roads or intersections [17-19] and downtown areas [19-21].

Researchers have found that pedestrian crashes differ based on socioeconomic conditions, land use and road design. Cottrill and Thakuriah note that greater numbers of pedestrian crashes occurred in low income and high minority census tracts in Chicago's metropolitan area [22]. Similarly, Loukaitous–Sideris and Liggett found relatively high rates of pedestrian crashes in low income and high percent Latino areas of Los Angeles [23]. Ukkusuir et al. studied pedestrian crashes in New York and found the likelihood of pedestrian crashes increased in census tracts with greater numbers of schools and transit stops, where there was a greater amount of industrial and commercial land use, and as the number of traffic lanes increased [24]. However, Clifron, Burnier and Akar found a negative association with pedestrian injury severity and transit access in Baltimore [25]. Kuhlmann and colleagues found pedestrian crashes in Denver were closer to downtown and significantly associated with population density, liquor store outlet density and the number of people who walked to work [20].

Other than the study by Kuhlman et al., few studies have been conducted to examine pedestrian crashes in the Mountain West region of the US [20]. The Mountain West is unique from the rest of the US in that it has experienced some of the fastest population growth and demographic transition in the nation [26]. Clark County, Nevada has many unique urban design characteristics which may influence pedestrian crash rates. It is a highly urban, yet sprawling metropolis. It was developed along a grid-design with high-speed arterial streets, which is where pedestrian crashes most frequently occur [27]. Additionally, the population in Clark County increased by 83% between 1990 and 2000 [28] and another 41.8% between 2000 and 2010 [29].

In 2008, Nevada was ranked 5th highest in the nation for the number of pedestrian fatalities per 100,000 population [12]. Seventy-five percent of pedestrian injuries in Nevada occur in Clark County, where seventy-five percent of the population lives [30]. Las Vegas was ranked the 6th most dangerous metro area for walking by Transportation for America in their *2011* report [27]. Clark County, Nevada was selected for this study because it has not been studied previously, because of its high rates of pedestrian crashes and because if it's unique urban design characteristics. The purpose of this study was to describe the current pedestrian injury and death (pedestrian crash) characteristics in Clark County, NV and to determine if there is a significant relationship between pedestrian crashes and socio-economic variables by census tract. Additionally, the researchers sought to describe pedestrian crash characteristics (i.e. time of day, weather conditions, pedestrian behavior, etc) which have not been well studied in the region.

Methods

Data

Police departments from Clark County, NV municipalities (Las Vegas, North Las Vegas, Henderson and Boulder City) submit detailed data of all pedestrian crashes reported to police into an electronic data base. Data for crashes reported between January 2009 and December 2011 were obtained from the University of Nevada, Las Vegas, Transportation Research Center for secondary analyses.

For the three year period of 2009 to 2011, there were a total of 1712 pedestrians hit by a motor vehicle which resulted in either a pedestrian injury or death (pedestrian crashes). Two hundred and thirty-seven of these crashes were missing complete location details and could not be matched to the appropriate census tract. Because the purpose of this study was to evaluate pedestrian crashes by census tract socioeconomic variables, those crashes were eliminated from the analysis. Additionally, 20 of the 487 census tracts in Clark County are rural. This study focused on urban pedestrian crashes, thus the 20 rural census tracts were removed from analysis.

Data Analysis

Descriptive analyses of pedestrian crashes were conducted using SPSS 20. Frequencies and rates of pedestrian crashes, pedestrian injuries and pedestrian deaths were calculated for the following characteristics: day of the week, time of day, weather conditions, road conditions, posted speed, driver/pedestrian under the influence of drugs or alcohol, crashes location (i.e. roadway, marked crosswalk, sidewalk, etc), pedestrian activity (i.e. crossing in a marked crosswalk, darting across a road outside of a marked crosswalk, etc), and pedestrian at fault. Chi square tests were utilized to determine if there were significant differences in characteristic variables for pedestrian injuries and pedestrian deaths.

The distribution of pedestrian crashes by census tract was skewed to the right with a large proportion of census tracts reporting zero pedestrian crashes (excessive zeros). Because of this, a zero-inflated negative binomial (ZINB) regression analysis was utilized to determine if there was a significant relationship between pedestrian crashes and socio-economic variable by urban census tracts. ZINB regression analysis is a modification of Poisson regression. Poisson regression is the appropriate tool for analyzing count data. However, when there is over dispersion or an excessive number of zeros, a Poisson regression is inefficient and ZINB regression is preferred [31]. ZINB regression analysis was determined to be the appropriate method for analysis because the data were count data and because 28% of census tracts had 0 pedestrian crashes, resulting in an excessive number of zeros. SAS 9.3 was used for this analysis. The dependent variable was pedestrian crashes per census tract. Independent variables included: median household (HH) income, percent black, percent Hispanic, percent white, median age, acres of land in the census tract, and population density (total population/acres in tract). Independent variable data came from the U.S. Census Bureau's 2010 American Community Survey 5 year estimates.

Lastly, ArcGIS was used to visualize pedestrian injury and death by significant independent variables identified in the zero-inflated regression model. This analysis enabled us to determine where pedestrian injuries and deaths occurred and clustered throughout Clark County's urban area.

Results

Descriptive Results

Between January 1, 2009 and December 31, 2011, 1467 police reported pedestrian crashes occurred in Clark County's urban areas. The number of pedestrian crashes per census tract ranged from 0 (28% of tracts) to 61. Of the 1467 pedestrian crashes, 1394 resulted in non-fatal injury while 73 resulted in death. The range for pedestrian injuries per census tract was 0 (28.3% of tracts) to 58 and the range of pedestrian deaths per census tract was 0 (88.5% of tracts) to 3. There was not a significant difference in the number of crashes, injuries or deaths over the three year period (Table 1). The most dangerous day to be a pedestrian was Friday with the highest percentage of total crashes (18.5%), injuries (18.1%) and deaths (26%) occurring on that weekday (Table 1).

Environmental characteristics of pedestrian crashes, injuries and fatalities are presented in Table 2. The majority of pedestrian crashes in Clark County, NV occurred during the day (58%), when it was clear (85%) and the roads were dry (95%). The most common posted speed limits where pedestrian crashes occurred were 35 mph (28%) or 45 mph (28%). The majority of pedestrian crashes happened in a marked crosswalk at an intersection (28%) or in the roadway outside of a marked crosswalk (28%); however, for 19% of cases the police did not report where the crash occurred. There were significant differences in some environmental characteristics when pedestrian injuries and deaths were compared. When compared to injury crashes, crashes resulting in death were more likely to occur at night ($p<0.01$), when it was cloudy ($p<0.01$), when the posted speed was 45 mph ($p<0.01$), and when the pedestrian was crossing the road but not in a marked crosswalk ($p<0.01$) (Table 2).

Table 3 includes human characteristics of pedestrian crashes, injuries and fatalities. The majority of pedestrian crashes happened when the person was entering or crossing the road at a specified location (60%) or walking, jogging, running (14%); however in 19% of crashes the pedestrian behavior at the time of the crash was not recorded. Pedestrians were deemed to be at fault 37% of the time and of that, 32% of the time the pedestrian was darting across the street or failing to obey the traffic signal, 2% of the time the pedestrian was not visible to the driver and 1% of the time the pedestrian was either illegally in the roadway (i.e. laying in the road) or inattentive (i.e. talking, eating, etc). When the pedestrian was struck by a vehicle while darting across a street or failing to obey a traffic signal, 65% of the time they were outside of a marked crosswalk. The pedestrian was suspected of being under the influence of alcohol or drugs in 3% of crashes, and the driver was suspected of being under the influence of alcohol or drugs in 4% of crashes. Significant differences between pedestrian injuries and deaths occurred across human characteristics. Fatal crashes were more likely to occur in the roadway but outside of a marked crosswalk (52%) than crashes that resulted in injury (26%) ($p<0.01$). The percent of pedestrians who were walking, jogging, running was higher (29%) for pedestrian deaths than injuries ($p=0.02$) and the police determined that the pedestrian was at fault (64%) more frequently ($p<0.01$) for death as compared to injury events. Additionally, pedestrians were suspected of being under the influence of alcohol or drugs (14%) and drivers were suspected of being under the influence of alcohol or drugs (10%) significantly more frequently when crashes resulted in death as compared to an injury event ($p<0.01$).

Zero-inflated Regression Results

A zero-inflated regression analysis was utilized to determine the relationship between the number of pedestrian crashes and independent variables by census tract. Independent variables were: median household (HH) income, percent black, percent Hispanic, percent white, median age, tract acres, and population density (total population/acres). A zero-inflated regression analysis consists of two parts, a logit model and a negative binomial regression model. In the logit model (to predict excessive zeros), total population was significant ($p=0.04$). The negative binomial regression model was significant ($p<0.01$). Percent Hispanic ($p<0.01$), median age ($p<0.01$), median household income ($p<0.01$) and population density ($p<0.01$) were significant predictors of pedestrian crashes by census tract. For these data, the expected change in log of pedestrian crashes was positive for percent Hispanic (exp=0.01) and median age (exp=0.03) and negative for median household income (exp= -0.03) and population density (exp= -0.04).

ArcGIS maps were created for significant independent variables and pedestrian injuries/deaths (Figure 1 and Figure 2). The maps allow for the visualization of clusters of pedestrian injuries in census tracts with a high percent Hispanic population and a low median household income. Pedestrian deaths were distributed more evenly across the metropolitan area than were injury crashes.

Discussion

The most interesting finding in this study was that pedestrian crashes were inversely related to population density. Surprisingly, population density was found to be protective factor for pedestrian crashes. This differs from findings in other metropolitan areas which found that injuries were greater in areas with higher population densities [20,32,33]. One potential explanation is that, because of higher population density, pedestrian traffic volume increases as well as driver awareness. Observing walkers might heighten a driver's awareness of pedestrians and result in more cautious driving. This line of thinking is supported by a study that found as pedestrian flow increases, crash rate decreases [34], but others have found the opposite [35-37]. It would have positive implications for the public health agenda if pedestrian traffic volume improves pedestrian safety, as promoting walking enhances health.

Additional explanations for the inverse relationship between pedestrian crashes and population density include: reduced traffic speed in heavily populated areas, more crosswalks in densely populated areas and social pressure. We found that the number of pedestrian crashes was higher in areas with higher speed limits. In densely populated areas, the traffic load may reduce vehicle speeds, which is likely to reduce pedestrian crash rates. In areas of higher population density it is also possible that streets are built with a grid design with crosswalks at every corner in contrast with areas with lower population density where there may be long distances between crosswalks. Lastly, as population density increases, the number of people walking increases. If other people are waiting for a walk signal at an intersection, there may be social pressure to conform and comply with other people's behavior. Behavior theorist would posit that there is increased social pressure to obey traffic signals when others are obeying traffic signals [38].

Based on the demographic distribution of Clark County, it is likely that the inverse relationship between pedestrian crashes and population density is a result of high car ownership in densely populated census tracts. In examining the ArcGIS maps (Figure 1 and Figure 2), pedestrian injuries cluster in census tracts that experienced population decline (i.e. lower population density) between 2009 and 2011 and also have the highest percentage of households without cars [39,40]. Because this geographic area of the city has a higher percentage of households without cars, it is likely that residents walk for utilitarian purposes. This suggests that pedestrian crashes are a social justice concern, because those most dependent on walking for utilitarian purposes are at greatest risk for pedestrian injury or death. This is similar to previous studies, which found that pedestrian crashes cluster in low income, high percent Hispanic neighborhoods [22,23]. Further ecological studies are warranted to understand the social and environmental characteristics of neighborhoods with high pedestrian injury/death in order to make them more conducive to walking, physical activity and health.

We were surprised that the majority of pedestrian crashes occurred during daytime and when alcohol or drugs were not suspected. We hypothesized the opposite, more pedestrian crashes would occur at night and alcohol or drugs would be suspected for either the driver or pedestrian. Pedestrian fatalities, however, were significantly more likely to happen at night with the suspicion of drugs and alcohol. This is similar to previous findings that alcohol increases subsequent mortality after being involved in a pedestrian crash [41]. This information could be used to create a social marketing campaign to make drivers aware of pedestrians during the day as well as at night and to encourage pedestrians to use protective behaviors at all times.

In eighty-seven percent of the instances when the police determined the pedestrian was at fault, the pedestrian was darting or failing to obey a traffic signal. Additionally, pedestrians were more likely to be hit in a crosswalk or in the road when entering or crossing the road at a specified location. These data can also be used as the basis for social marketing campaigns to educate both drivers and pedestrians about how and where pedestrians get hit.

This information may also be used when considering policies to improve road designs in high risk areas. By identifying 'hot spots' for pedestrian crashes, data could be used to better understand the dynamics of pedestrian crashes in those targeted areas. For example, poor crosswalk quality, long distances between crosswalks, or non-signalized crosswalks (crosswalks without a signal to indicate when to walk or not walk) may contribute to pedestrian crashes. Additionally, qualitative research could be conducted to understand why pedestrians engage in risky behaviors (i.e. darting or failing to obey traffic signals). Based on these findings, the resources available could be used most effectively to improve pedestrian safety.

Limitations

This study is not without limitations. Because our design was cross sectional, causation cannot be determined. A large amount of data were missing for some of the human characteristics, especially pedestrian activity such as whether the pedestrian or driver was under the influence of drugs or alcohol, and the precise location of the crash. Police reports only indicated if they believed that the pedestrian was at fault. It was not possible to know how frequently the driver was determined to be at fault. Lastly, the study included only police data. Previous research suggest that as many as fifty percent of pedestrian crashes go unreported [42,43]. Further, we only know the number of crashes, not the total numbers of pedestrians or vehicles that use specific roads or intersections. It may be that numbers of crashes simply reflect the number of pedestrians and vehicles that use specific sections of road, not pedestrian or vehicle behaviors, or built environment characteristics.

Conclusions

Pedestrian crashes are a barrier to physical activity and efforts to reduce them should be undertaken. Based on the Social Cognitive Theory, reducing pedestrian crashes may help to promote walking both for pleasure or utilitarian purposes. Significant predictors of pedestrian crashes were median household income, percent Hispanic population, population density and median age. Additionally, more pedestrian crashes occurred during the day when alcohol and drugs were not suspected. These data could be utilized to develop educational or outreach efforts to increase driver and pedestrian knowledge of pedestrian safety issues. More ecological research is needed in areas of high pedestrian crashes to understand specific conditions in the built environment that might contribute to crashes. By identifying 'hot spot' areas within a community, further research can be conducted to ascertain issues that contribute to pedestrian injury/death. Resolution of issues could positively impact physical activity and walkability in a metropolitan area.

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Table 1: Descriptive Characteristics of Pedestrian Crashes, Injury and Fatality

Descriptive Characteristics	Pedestrian Crashes n	Pedestrian Crashes %	Pedestrian Injury n	Pedestrian Injury %	Pedestrian Fatality n	Pedestrian Fatality %	Chi Square Injury v Fatality
Total	1467	100	1394	0.95	73	0.05	
Crash Year							
2009	482	0.33	460	0.33	22	0.30	0.74
2010	522	0.36	493	0.35	29	0.40	
2011	463	0.32	441	0.32	22	0.30	
Day of the week							0.14

Monday	200	0.14	194	0.14	6	0.08	
Tuesday	218	0.15	208	0.15	10	0.14	
Wednesday	207	0.14	203	0.15	4	0.05	
Thursday	209	0.14	195	0.14	14	0.19	
Friday	272	0.19	253	0.18	19	0.26	
Saturday	216	0.15	204	0.15	12	0.16	
Sunday	145	0.10	137	0.10	8	0.11	

Table 2: Environmental Characteristics of Pedestrian Crashes, Injury and Fatality

	Pedestrian Crashes		Pedestrian Injury		Pedestrian Fatality		Chi Square Injury v Fatality
Environmental Characteristics	n	%	n	%	n	%	
Time of Day							<0.01*
Dawn	11	0.01	9	0.01	2	0.03	
Day light	848	0.58	823	0.59	25	0.34	
Dust	30	0.02	30	0.02	0	0.00	
Night (dark)	557	0.38	516	0.37	41	0.56	
Missing	21	0.01	16	0.01	5		
Weather Conditions							<0.01*
Clear	1247	0.85	1202	0.86	45	0.62	
Cloudy	182	0.12	158	0.11	24	0.33	
Raining	32	0.02	30	0.02	2	0.03	
Missing	6	0.00	4	0.00	2	0.03	
Road Conditions							0.013*
Dry	1394	0.95	1339	0.96	55	0.75	
Wet	59	0.04	52	0.04	7	0.10	
Missing	14	0.01	3	0.00	11	0.15	
Posted speed - mph							<0.01*
≤15	94	0.06	94	0.07	0	0.00	
25	308	0.21	300	0.22	8	0.11	
30	79	0.05	77	0.06	2	0.03	
35	406	0.28	392	0.28	14	0.19	
40	8	0.01	7	0.01	1	0.01	
45	410	0.28	380	0.27	30	0.41	
50	2	0.00	2	0.00	0	0.00	
>50	24	0.02	17	0.01	7	0.10	
Missing	136	0.09	125	0.09	11	0.15	
Location of crash							<0.01*
Marked crosswalk at intersection	411	0.28	398	0.29	13	0.18	
In roadway outside crosswalk	406	0.28	368	0.26	38	0.52	
Sidewalk	179	0.12	173	0.12	6	0.08	
Intersection w/o crosswalk	61	0.04	59	0.04	2	0.03	
Driveway	41	0.03	41	0.03	0	0.00	

Shoulder	11	0.01	10	0.01	1	0.01	
Median	18	0.01	17	0.01	1	0.01	
Other	66	0.04	64	0.05	2	0.03	
Missing	274	0.19	264	0.19	10	0.14	

Table 3: Human Characteristics of Pedestrian Crashes, Injury and Fatality

Human Characteristics	Pedestrian Crashes		Pedestrian Injury		Pedestrian Fatality		Chi Square
	n	%	n	%	n	%	Injury v Fatality
Pedestrian Activity							0.02*
Crossing street at specific location	883	0.60	846	0.61	37	0.51	
Walking, jogging, running	203	0.14	182	0.13	21	0.29	
Working in road	5	0.00	5	0.00	0	0.00	
Standing	40	0.03	37	0.03	3	0.04	
Approaching or leaving a car	18	0.01	18	0.01	0	0.00	
Pushing or working on a car	6	0.00	6	0.00	0	0.00	
Other	40	0.03	37	0.03	3	0.04	
Missing	272	0.19	263	0.19	9	0.12	
Pedestrian at fault							<0.01*
Yes	545	0.37	498	0.36	47	0.64	
Not determined	922	0.63	896	0.64	26	0.36	
If at fault, pedestrian action							
Darting, failure to obey traffic signal	476	0.32	433	0.31	43	0.59	0.58
Not visible	33	0.02	30	0.02	3	0.04	
Lying or illegally in roadway	20	0.01	19	0.01	1	0.01	
Inattentive (talking, eating)	16	0.01	16	0.01	0	0.00	
Pedestrian under the influence of drugs or alcohol							<0.01*
Alcohol or drugs suspected	44	0.03	34	0.02	10	0.14	
Either suspected	1023	0.70	990	0.71	33	0.45	
Missing	400	0.27	370	0.27	30	0.41	
Driver under the influence of drugs or alcohol							0.01*
Alcohol or drugs suspected	53	0.04	46	0.03	7	0.10	
Either suspected	1134	0.77	1085	0.78	49	0.67	
Missing	280	0.19	263	0.19	17	0.23	

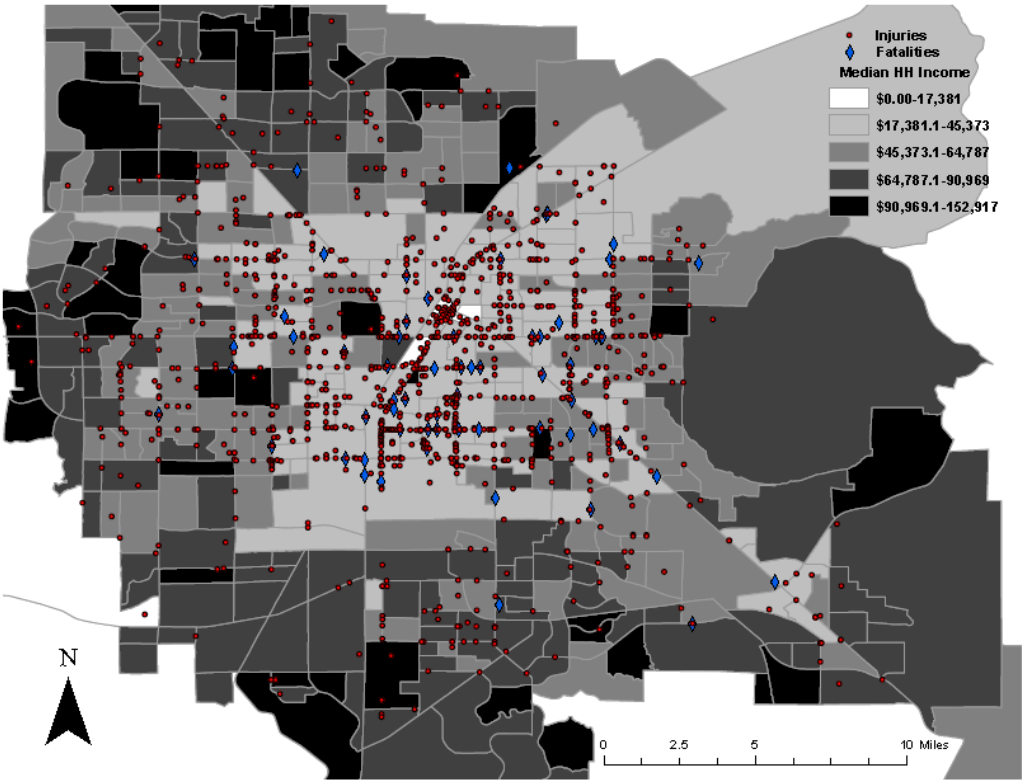

Figure 1: Pedestrian Injuries and Fatalities by Median Household Income in Clark County, NV

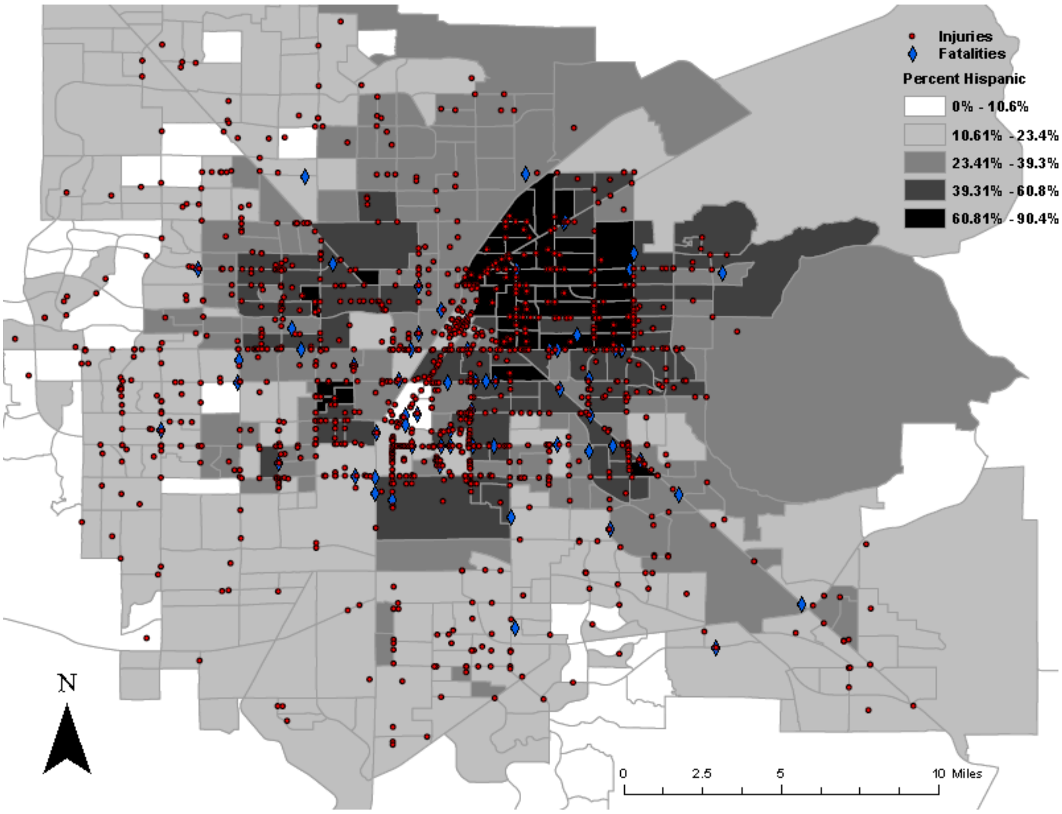

Figure 2: Pedestrian Injuries and Fatalities by Percent Hispanic Population