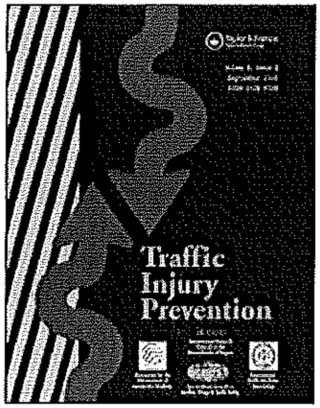

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The Relationship of Pedestrian Injuries to Socioeconomic Characteristics in a Large Southern California County

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Objectives: The goal of this study is to explore the relationship between pedestrian injuries and socioeconomic characteristics.

Methods: Pedestrian collisions were identified in the data of the California Statewide Integrated Traffic Records System (SWITRS), which is assembled from police crash reports by the California Highway Patrol Information Services Unit. Four thousand crashes were identified and geocoded within the census tracts in a county population of 2,846,289 over a 5-year period. Population and population characteristics for census tracts were obtained from the 2000 U.S. Census.

Results: The percentage of the population living in households with low income (less than 185% of the federal poverty level) was the strongest predictor of pedestrian injuries. One fourth of census tracts had less than 8.7 percent of residents with low income and averaged 11 per 100,000 pedestrian crashes annually. One fourth of the census tracts had more than 32.2 percent of residents with low income and an average of 44 pedestrian crashes per 100,000 annually. Negative binomial regression showed that with each 1 percent increase in the percentage of residents with low income was associated with a 2.8 percent increase in pedestrian crashes. The percentage of residents age 14 years or less, adult residents who had not completed high school, residents who spoke English less than "very well" and spoke another language at home, and the population density were each associated with a higher frequency of pedestrian crashes. However, when low income was added to these 4 regression models, the relationship between low income and pedestrian crashes increased.

Conclusions: Our study showed that pedestrian crashes are 4 times more frequent in poor neighborhoods and that neither age of the population, education, English language fluency, nor population density explained the effect of poverty.

Keywords Pedestrian; Injuries; Socioeconomic status; Census tract; Geographic information systems

INTRODUCTION

Motor vehicle collisions continue to impose a large personal and financial burden on society and on the delivery of health services in the United States. In 2000 the cost of motor vehicle collisions in the United States was estimated at 230.6 billion dollars (Blincoe et al. 2002). Pedestrians struck by motor vehicles typically fare poorly, and such crashes frequently result in long-term disabilities or death (Peng and Bongard 1999; Shankar 2003). Despite advances in automobile safety technology and equipment, improved roads and crosswalks, and driver training and public awareness, over 4000 pedestrians die every year due to motor vehicle collisions, and about 70,000 struck pedestrians sustain injuries (National Highway Traffic Safety Administration 2009).

A number of complex etiological factors contribute to the incidence of pedestrian collisions, including motor vehicle speed, average daily traffic flow, alcohol involvement, and environmental issues, as well as socioeconomic status (SES; Stokols 1992; "Alcohol Involvement in Pedestrian Fatalities—United States, 1982–1992" 1993; Stokols et al. 1996; Hilton 2006). Moreover, pedestrian deaths or disability create a greater financial burden on those living in an already economically strained situation (Peden 2004). Although there may be several proxies to SES, such as family income or education level, the fact remains that pedestrian injuries have a greater negative impact on those of lower SES. Previous studies have shown that disparities in the frequency of child pedestrian injuries exist among populations of various SES with regard to the incidence and outcomes of pedestrian collisions (Bagley 1992; Rivara and Barber 1985; Agran et al. 1998; Laflamme and Diderichsen 2000; LaScala

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et al. 2004). Two studies using data from San Francisco found a relationship between SES and injuries to pedestrians of all ages (Lascala et al. 2000; Wier et al. 2009).

Individuals from these backgrounds are affected a greater percentage of times, have fewer social supports in place, and may use emergency services less frequently (Mock et al. 1997; Laflamme and Diderichsen 2000; Braver 2003; Nantulya and Reich 2003). Pedestrian injuries are also more prevalent in areas with high measures of social disadvantage, such as crime and domestic unrest (Bagley 1992). The effects of low income and household crowding have also been shown to be independent risk factors for pedestrian injuries (Rivara and Barber 1985). Still other studies have linked poverty and the lack of English-language fluency as a risk factor for pedestrian injuries (Agran et al. 1998). Race and ethnicity also play a large role in pedestrian injuries and fatalities. Recent national data show that all minorities of all age groups (with one exception) are more likely to be involved in a fatal nonoccupant collision than the non-Hispanic white population (Hilton 2006). Underreporting of pedestrian injuries among minorities is also cited in the literature and would likely increase the burden of disease in certain ethnicities (Sciortino et al. 2005). Cultural-related attitudes and perceptions concerning safety and public health, access to health care, and limitations in their exposure to health promotion also may prove to be important reasons for the increased incidence of pedestrian injuries in the United States. The theory of social ecology suggests that the disproportionately higher incidence of injuries is likely due to an amalgamation of various environmental and individual-level factors, such as population density, vehicle miles traveled, alcohol consumption, risky behavior patterns, and demographic factors, such as age, gender, education, socioeconomic status (Stokols 2000).

Orange County, California, is a model location to study health disparities, because the population features striking socioeconomic diversity. Although it is portrayed in the media as a wealthy and idyllic California beach region, residents in several small communities within the county live in poverty and face several barriers to achieving positive health outcomes. As an example of diversity within Orange County, recent U.S. Census data show that the median household income in Laguna Beach is $74,808, with a 92 percent Caucasian population and only 5 percent of individuals living at or below the poverty level. In contrast, of the individuals living in the 92701 ZIP code in Santa Ana, 26.4 percent live below the poverty level; this community is 88.3 percent Hispanic, with a median household income of $33,728 (U.S. Census Bureau 2003). The previously mentioned studies on motor vehicle crashes involving pedestrians would suggest that these individuals in Santa Ana are struck by motor vehicles at much higher rates and, when struck, face poorer outcomes, including higher morbidity and mortality.

Injuries, and in particular pedestrian injuries, have a strong spatial–geographic distribution (Braddock et al. 1994; Lascala et al. 2000, 2004; Sciortino et al. 2005; Pulugurtha et al. 2007). Geographic information systems (GIS) software provides valuable tools in regards to the spatial distribution of injuries and may assist in identifying key risk factors in the environment and in the individual. The importance of GIS is delineated by the plethora of studies identifying the geographic distribution of high crash zones (Noland and Quddus 2004; Dissanayake et al. 2009; Hansen et al. 2009; Schuurman et al. 2009; Warsh et al. 2009; Weiner and Tepas 2009). A number of studies have illustrated the importance of the geographic distribution of pedestrian injuries as it might pertain to ecological factors and preventative measures at a city level (Lightstone et al. 2001; Noland and Quddus 2004; Pulugurtha et al. 2007; Wier et al. 2009). Two of these studies used the city of San Francisco, California, as the area of interest (Lascala et al. 2000; Sciortino et al. 2005).

This article looks at all age groups and allows comparisons to be made among youth, adult, and senior age groups. Other groups have studied child pedestrian injuries or were restricted to the city of San Francisco. Our study of Orange County, California, looks at an area approximately 17 times the size of San Francisco by square miles, with a population nearly 4 times as large spread throughout urban, suburban, and rural areas. The goal of this study is to determine how environmental and individual level predictors (demographics), such as socioeconomic differences, translate into disparities of pedestrian collisions on a larger geographic distribution (county level) by using GIS.

METHODS

Pedestrian collisions were identified in the data of the California Statewide Integrated Traffic Records System (SWITRS), which is assembled from police crash reports by the California Highway Patrol Information Services Unit. Pedestrian collisions were defined as collisions with any injuries to pedestrians. To preserve the independence of the observations, each collision was counted once regardless of the number of injured pedestrians. Collisions from 2000 to 2004 were selected to minimize error due to application of 2000 census data to later years. The data were geocoded by Crossroads Software, Brea, California, using the distance and direction of the point of impact from the nearest intersection indicated in SWITRS. Population and population characteristics for census tracts were obtained from the 2000 U.S. Census (U.S. Census Bureau 2003).

Measures

We originally defined poverty (percentage of individuals with family incomes less than 100% of the poverty level) and near poverty (percentage of individuals with family incomes from 100% to less than 185% of the poverty level). One hundred eighty-five percent of the federal poverty level is the maximum income eligible for the Women, Infants and Children nutrition program in California and for reduced price school meals (California Department of Health 2009; *Eligibility Manual for School Meals: Federal Policy for Determining and Verifying Eligibility* 2009).

Two age groups were used: percentage 0–14 years and percentage 65 and older. The effect estimates for these groups are relative to the remaining group, age 15–64 years. Less than high school education was defined as the percentage of the population age 25 years or older that did not graduate from high school. The percentage of the population age 5 and older, who speak a language other than English at home, was further stratified into those who spoke English very well and those who spoke English less than very well, as reported by the census respondent for each household. The effect estimates for these groups are relative to the population that speaks English at home. Population density was converted to a percentage of the maximum density (16,623/km^2) for the regression analysis.

We mapped the pedestrian collisions using ArcMap (version 9.2, ESRI, Redlands, Calif). We joined census tract boundaries to the maps and produced counts of pedestrian collisions by census tract (U.S. Census Bureau 2003). These data were merged with the census characteristics and analyzed using Stata (version 10.1, StataCorp, College Station, Tex). Because the variance of the collision counts was much larger than their mean, we chose negative binomial regression to control for overdispersion in the data. The model assessed the relationship between population characteristics and pedestrian collision counts, controlling for population size. Thus, the regression coefficients measured the increased risk associated with the census characteristics, assuming that baseline risk is proportional to the population. Colinearity between the population characteristics was assessed with Pearson product-moment correlation coefficients.

To further illustrate the effect of low income on pedestrian injuries, the census tracts were divided into quartiles percentage of poverty and near poverty. Collision was defined as the average annual number of pedestrian collisions divided by the total population. This ratio is not a rate because it uses the number of pedestrian collisions occurring within the census tract rather than all pedestrian collisions to census tract residents.

RESULTS

We identified 4222 collisions with 4524 injured pedestrians, a ratio of 32 injured pedestrians per 100,000 population annually (95% confidence interval [CI] 31–33). The ratio was 41 (95% CI: 39–43) for age 0–14, 28 (95% CI: 27–29) for age 15–64, and 31 (95% CI: 28–34) for age 65 and older. Age was unknown for 53 injured pedestrians (1%).

Exactly 4000 (95%) of these collisions were geocoded to a specific location, and 3988 cases were geocoded to a census tract (please refer to Figure 1). Five hundred sixteen of 577 census tracts (89%) had one or more collisions. Three census tracts had 33, 48, and 99 collisions, respectively, more than three standard deviations above the mean of 6.9 collisions. The characteristics of the census tracts are shown in Table I.

The results of the negative binomial regression are shown in Table II. The two age variables were included in the same regression, as were the two poverty variables and the two language variables. Near poverty was a stronger predictor of pedestrian injuries than poverty. Because we had no reason to expect near poverty to be more strongly related than poverty to pedestrian injuries, we combined the poverty and near poverty categories. The percentage of the population age 14 years and younger with

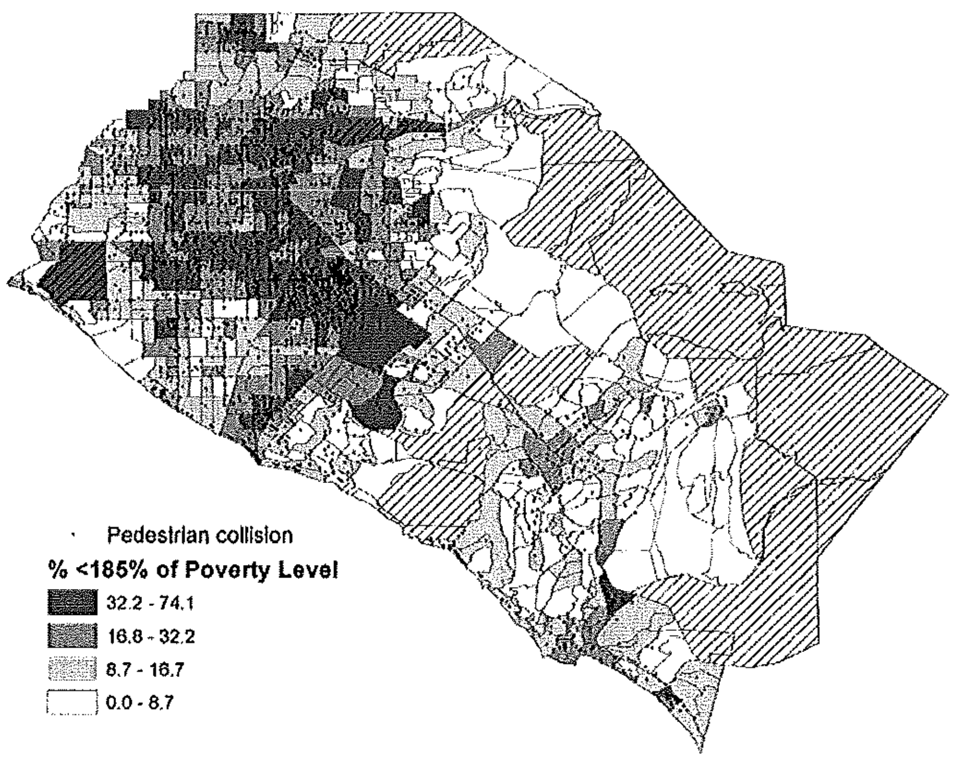

Figure 1 Map of pedestrian collisions (dots) by percentage poverty and near poverty. (Hash-marked areas have a population density of less than 10/km^2.)

Table I Mean and standard deviation of census variables by census tract, Orange County, California, 2000, $n = 577$ census tracts

Variable	Mean	Standard deviation	25th Percentile	75th Percentile
Age 0–14	22.2%	6.0%	19.3%	25.5%
Age 64+	10.5%	9.1%	5.7%	12.4%
Poverty and near poverty	22.3%	16.8%	8.7%	32.2%
<High school education	19.7%	19.2%	5.5%	28.9%
Speak other language at home, speak English very well	18.4%	8.3%	12.1%	23.6%
Speak other language at home, speak English less than very well	19.9%	17.3%	6.4%	30.4%
Population density/km^2 (% of maximum)	3150 (19.0%)	2229 (13.4%)	1762 (10.6%)	3864 (23.2%)
Pedestrian collisions	6.9	7.6	2	10

incomes of poverty or near poverty level, with less than a high school education, that spoke other language at home, and did not speak English and the population density were all related to the number of pedestrian injuries. The largest regression coefficients were for the percentage of poverty and near poverty. Because of the large correlations between poverty and other variables, we do not present regression models with more than one independent variable. However, inclusion of any of the other variables did not decrease the association between poverty and the collision ratio.

To determine whether the 3 census tracts with more than 30 cases had a disproportionate effect on the regression, we repeated the regression without these 3 census tracts. In the crude regression, the percentage change in collision ratios for a 1 percent change in population age 0–4 was reduced to 1.3 and for "speak other language at home," "speak English well" to 1.3. None of the other crude coefficients changed by more than 20 percent. The coefficient for poverty and near poverty decreased less than 3 percent.

Table III shows the annual collision ratio per 100,000 population by quartile of percentage of household below 185 percent of poverty level. The collision ratio increased with each quartile.

DISCUSSION

In Orange County, California, in a univariate regression model at the census tract level, statistically significant predictors of vehicle pedestrian injury collisions include poverty, population density, English-language fluency, and education. Among all of these variables poverty was clearly the strongest predictor of frequency of pedestrian collisions. Some experts suggest that those from a lower SES engage in riskier behavior and are less likely to be aware of public safety issues (Campos-Outcalt et al. 2002). Low-income individuals may walk more in environments with more traffic than high-income individuals (Lascala et al. 2000; Wier et al. 2009).

In our analysis we assumed that poverty and near poverty would have the same effect on pedestrian collisions. However, the effect of near poverty may be a reflection of the risk associated with demographic transitions, such as the acculturation of recent immigrants (Anderson et al. 1998). To speculate further, those at near poverty may have higher employment levels than poor individuals, requiring near-poor individuals to leave their homes more often and risk traffic exposure. This may include working multiple low-paying jobs, requiring frequent travel between job sites, increasing the exposure to traffic.

The ratio of pedestrian injuries to population in our study area was greater than national rates of pedestrian injury, especially for age 0–14 years (National Highway Traffic Safety Administration 2009). In our results, the pedestrian injury ratio was only slightly higher for age 65 years older and the proportion of older residents was not associated with more pedestrian injuries in a census tract. In U.S. data, older individuals have a higher fatality rate but a lower injury rate than younger adults (National Highway Traffic Safety Administration 2009).

GIS used in this study allowed us to link collision data with census tract data. This application may prove beneficial in assisting city and county policymakers with educational, enforcement, and environmental decisions. The map displayed the association of one community-level risk factor with collisions, but to individuals familiar with the area the map may suggest other associations that might lead to further research and interventions.

Table II Percentage change in collision ratios for 1 percent change in independent variable, negative binomial regression controlling for population size, Orange County, California, 2000–2004, $n = 577$ census tracts

Variable	% Change	95% CI	Correlation with poverty and near poverty (r)
Age 0–14	1.8	0.4–3.2	0.49
Age 64+	−0.5	−1.7 to 0.6	0.15
Poverty Near poverty	1.2 4.2	−0.1 to 2.5 3.1–5.3	— —
Poverty + near poverty	2.8	2.4–3.3	—
<High school education	2.1	1.7–2.4	0.89
Speak other language at home, speak English very well	1.0	−0.3 to 2.3	0.50
Speak other language at home, speak English less than very well	1.8	1.2–2.4	0.88
% of Maximum population density	1.1	0.5–1.7	0.66

Table III Pedestrian collisions, population, and annual collision ratio per 100,000 population by quartile poverty and near-poverty level

% Poverty and near poverty	Census tracts	Pedestrian collisions	Population	Collision ratio
0–8.6	144	336	605,834	11.1
8.7–16.6	144	622	659,889	18.9
16.7–32.1	144	1097	703,238	31.2
32.2–74.1	145	1933	877,328	44.1
Total	577	3988	2,846,289	28.0

The study showed an increased frequency of collisions in specific areas that are known to be commercial or recreational destinations. It is possible that the risk of injuries in these areas could be due to factors other than the characteristics of the residents in the census tracts, although data do suggest that most pedestrian injuries occur within close proximity of their residences (Lightstone et al. 2001).

Clearly, this study points toward disparities in injuries that are a reflection of poverty. These results are consistent with previous research that looked at pedestrian injury disparities on a smaller geographic scale (city level; Agran et al. 1998; Lascala et al. 2000; Noland and Quddus 2004; Wier et al. 2009). It is likely also that individuals of lower socioeconomic status and minorities are underreported by the police and that they may use emergency services far less than their counterparts (Sciortino et al. 2005). Policymakers should look for interventions to decrease injuries in poor neighborhoods to address these disparities.

LIMITATIONS

Census tract boundaries typically follow arterial streets, and the census tract shapefiles that we used are not as precise as the collision geocoding provided by Crossroads Software. Thus, collisions occurring near census tract boundaries may have been assigned to the wrong census tract. However, we would expect this misclassification to be nondifferential with respect to poverty and other population characteristics and to diminish measures of association.

These group-level data are appropriate for analyzing social processes that occur at the level of the census block group or neighborhood (Schwartz 1994). However, if the causal processes occur at the family or individual level, the analysis of neighborhood-level data may suffer from ecologic bias (Morgenstern 1995). Furthermore, a multivariate model of ecologic data may not adequately control for confounding at the individual level (Greenland 1992).

CONCLUSION

Our study showed that pedestrian crashes are 4 times more frequent in poor neighborhoods and that neither age of the population, education, English-language fluency, nor population density explained the effect of poverty. The results demonstrate significant geographic- and demographic-level disparities in pedestrian crashes. Further understanding of the complex environmental and individual-level factors can help direct educational programs, interventions, policy and ultimately improve injury disparities.

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