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Why more male pedestrians die in vehicle-pedestrian collisions than females: a decompositional analysis

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Abstract

Objective—Pedestrians account for a third of the 1.2 million traffic fatalities annually worldwide, and males are overrepresented. We examined the factors that contribute to this male-female discrepancy: walking exposure (kilometers walked per person-year), vehicle-pedestrian collision risk (number of collisions per kilometers walked), and vehicle-pedestrian collision case fatality rate (number of deaths per collision).

Design—The decomposition method quantifies the relative contributions of individual factors to death rate ratios among groups. The male-female ratio of pedestrian death rates can be expressed as the product of three component ratios: walking exposure, collision risk, and case fatality rate. Data sources included the 2008–2009 U.S. Fatality Analysis Reporting System, General Estimates System, National Household Travel Survey, and population estimates.

Setting—U.S.

Participants—Pedestrians age 5 and older.

Main outcome measures—death rate per person-year, kilometers walked per person-year, collisions per kilometers walked, and deaths per collision by sex.

Results—The pedestrian death rate per person-year for males was 2.3 times that for females. This ratio of male to female rates can be expressed as the product of three component ratios: 0.995

Contributors: MZ originated and designed the study, participated in data analysis, and led the writing. SZ conducted data analysis. JC and GS critically reviewed and substantially revised the manuscript. All authors had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis.

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for walking exposure, 1.191 for collision risk, and 1.976 for case fatality rate. The relative contributions of these components were 1%, 20% and 79%, respectively.

Conclusions—The majority of the male-female discrepancy in 2008–2009 pedestrian deaths in the U.S. is attributed to a higher fatality per collision rate among male pedestrians.

Keywords

Pedestrian; epidemiology; health disparities; gender

INTRODUCTION

Motor vehicle collisions are a major source of morbidity and mortality around the world, causing about 20 to 50 million injuries and 1.2 million traffic fatalities every year.[1–3] Vehicle-pedestrian collision fatalities (hereafter called "pedestrian deaths") represent a substantial proportion of all traffic causalities not only in developing and transitional countries, but also in developed countries.[1–4] They account for 54% of traffic deaths in Bangladesh, 39% in South Africa, 33% in Iran, 26% in China, and 21% in the United Kingdom.[4] In the United States (U.S.), 4,092 pedestrians died in 2009, representing 12% of all traffic fatalities.[5]

Males are overrepresented in pedestrian deaths in most countries. For example, males, who represented 49% of the U.S. population in 2009, accounted for 69% of the pedestrian deaths;[5] likewise, males accounted for 73% of pedestrian deaths in Mexico City in 1994–1997,[6] and 76% of pedestrian deaths in four South Africa cities in 2001–2004.[7] Understanding the factors contributing to elevated male pedestrian deaths is an essential first step in reducing total pedestrian deaths because rates in males are much higher than females.

One important determinant of risk for pedestrian death is exposure to traffic,[8–10] but other factors such as risk of being struck by a vehicle, and risk of dying if struck by a vehicle, are also important determinants of the vehicle-pedestrian collision death rate. However, no previous studies have simultaneously assessed the following three questions regarding elevated male pedestrian deaths: 1) Do males walk more than females? 2) Are males more likely to be struck by vehicles even if they walk the same distance as females? 3) Are males more likely to die if struck by vehicles? Our study objective was to estimate the relative contribution of these three factors to the male-female discrepancy in pedestrian death rates using the decomposition method to better understanding the different components of traffic death rates.[11–15] The existence of reliable U.S. indicators of walking exposure, vehicle-pedestrian collision risk (hereafter "collision risk") and vehicle-pedestrian collision case fatality rate (hereafter "collision case fatality rate") provided this opportunity.

METHODS

Data Sources

Data sources included the 2008–2009 U.S. National Household Travel Survey (NHTS) (walking exposure), the General Estimates System (GES) (collision data), the Fatality Analysis Reporting System (FARS) (collision fatality data), and resident population estimates from the Census. The NHTS is a national exposure survey that uses computer-assisted telephone interviews to collect information about personal and household characteristics, daily trips, and long-distance travel.[16] The participants are selected from the civilian, non-institutionalized U.S. population with list-assisted random digit dialing to landline telephones. Each respondent is assigned a sampling weight or a series of replicate weights to reflect their selection probability and to adjust for nonresponse, undercoverage, and multiple phones in a household.[16] For daily trips, respondents are instructed to keep a written diary of all trips made during a randomly assigned 24-hour day. Twenty-four-hour diary gave the estimates of kilometers walked. Although in NHTS the trip distance is reported in miles, we converted miles into kilometers, since most countries use the metric system. The 2008–2009 NHTS included 150,147 household interviews from April 2008 through May 2009.[16]

GES is a nationally representative sample of police-reported crashes.[17] Each year, approximately 45,000 crashes of all severities (property damage only, nonfatal injury, fatal injury) are selected at random from over 400 police jurisdictions in 60 study sites across the U.S. to provide national estimates.[17] GES provided the counts of vehicle-pedestrian collisions by sex.

FARS contains data for all motor vehicle crashes that result in at least one fatality within 30 days of the crash in the U.S.[18] It supplied the counts of vehicle-pedestrian collision deaths. U.S. census data contain resident estimates on July 1st.[19]

Because NHTS only collects survey data on residents aged 5 years and older, our study population was limited to pedestrians aged 5 years and over. The NHTS was conducted in 2008–2009, and thus kilometers walked are 2008–2009 estimates. Therefore, 2008–2009 GES,FARS and resident estimates were used for counts of collisions and deaths.

Decomposition Method

The decomposition method has been shown to be a valuable method for better understanding the different components of traffic death rates across population groups, time periods, and geographic regions.[11–15] As a measure of mortality, the population-based pedestrian death rate (a) in Formula 1 (below) is calculated as the number of pedestrian deaths from collisions divided by person-time of observation in the candidate population who can be pedestrians.[11] For example, the male pedestrian death rate is the number of male pedestrians who die from collisions within a specific calendar year divided by the mid-year estimate of number of males in that year. The pedestrian death rate (a) can be expressed as the product of three components: (b) walking exposure: the number of kilometers walked per person-years; (c) collision risk: the number of vehicle-pedestrian collisions per kilometers walked; and (d) collision case fatality rate: the number of deaths per vehicle-pedestrian collisions (Formula 1).[11] In other words, the risk of dying from vehicle-pedestrian collisions in a specific year equals the amount of walking within that year, multiplied by the risk of a collision while walking, multiplied by the risk of death when involved in collisions.

$$\begin{gathered}\textit{Pedestrian death rate}\,(a)=\textit{walking exposure}\,(b)\times\textit{collision risk}(c)\times\textit{collision case fatality rate}\,(d)\\ \frac{\#\textit{pedestrian deaths}}{\#\textit{person}-\textit{years}}(a)=\frac{\#\textit{kilometers walked}}{\#\textit{person}-\textit{years}}(b)\times\frac{\#\textit{collisions}}{\#\textit{kilometers walked}}(c)\times\frac{\#\textit{deaths}}{\#\textit{collisions}}(d)\end{gathered}\quad \text{Formula 1}$$

Using females as the referent group, we express the comparison of pedestrian death rate between males and females as a ratio (Formula 2).[11]

$$\frac{a_{male}}{a_{female}}=\frac{b_{male}}{b_{female}}\times\frac{c_{male}}{c_{female}}\times\frac{d_{male}}{d_{female}}=ratio_b\times ratio_c\times ratio_d \quad \text{Formula 2}$$

The ratio of the *b*s, *c*s, and *d*s express their contribution to the pedestrian death rate ratio between males and females in terms of magnitude and direction.

In addition, we can estimate the relative contribution (RC) of each component to the difference in pedestrian death rate with the following equation (Formula 3).[11] The method uses the natural logarithmic transformation of both sides of Formula 2, which has been described in other studies.[11] Only the absolute values are used as some values could be negative. This approach helps to identify the relative importance of individual components with regard to developing prevention strategies.

$$RC_i = \frac{|\ln(ratio_i)|}{|\ln(ratio_b)| + |\ln(ratio_c)| + |\ln(ratio_d)|} \times 100\% \quad \text{Formula 3}$$

where i = b,c,or d; ln stands for natural logarithmic transformation

Variables and Analysis

Our exposure variable was sex, and we compared pedestrian death rate, annual kilometers walked, collision risk, and collision case fatality rate between males and females. For annual kilometers walked, we accounted for the sampling weights, sampling strata, and sampling units in the NHTS.[16, 20] FARS was considered a census of fatal crashes, therefore, sampling weights were not applicable.

RESULTS

Pedestrian death rates

The pedestrian deaths were based on 8,228 out of 8,283 fatally injured victims in 2008–2009 FARS for the U.S. (Table 1). (Sex was missing for four subjects and age data was missing for 51.) The pedestrian death rate per 100,000 person-years for males (2.04) was 2.3 times the rate for females (0.87) (Table 2).

Components of the pedestrian death rates

Walking exposure: number of kilometers walked per person-year—The walking exposure was estimated based on 262,934 respondents who compiled a travel diary in the 2008–2009 NHTS. Males and females both reported walking about 183 kilometers annually on trips (0.5 kilometer every day) (Table 2).

Collision risk: collision rate per million kilometers walked—The collision risk was based on 3,806 out of 3,807 pedestrian victims from 2008–2009 GES in the U.S. (age was missing for one subject) The collision rate per million kilometers walked was 1.37 for males, and 1.15 for females (Table 2).

Collision case fatality rate per 100 crashe—During 2008–2009, approximately 8% of male pedestrians involved in collisions, and 4% of female pedestrians involved in collisions died (Table 2).

Contributions to the differences in pedestrian death rates

Using ratios—Table 2 shows the comparisons of males against females as ratios of pedestrian death rate per person-year, walking exposure, collision risk, and collision case fatality rate. The pedestrian death rate per 100,000 person-years for males (2.04) was 2.34 times the rate for females (0.87). Applying data in Table 2 and Formula 2, the fatality rate was decomposed as: 2.34 = 0.995 × 1.191 × 1.976.

Therefore, the magnitude of the difference in walking exposure (b_{male}/b_{female}) was minus 0.5 percent, the difference in collision risk (c_{male}/c_{female}) was plus 19.1 percent, and the difference in collision case fatality rate (d_{male}/d_{female}) was plus 97.6 percent. Each of these differences contributed to a 134% higher pedestrian death rate (a_{male}/a_{female}) when comparing males and females. In other words, since the walking exposure was minimally higher among females, this component did not contribute much to the difference in pedestrian death rate between sexes. The collision risk and collision case fatality rate were higher among males. Therefore, each component contributed to a positive male-to-female death rate ratio.

Using natural logarithmic transformation—The relative contribution of the differences in walking exposure, collision risk, and collision case fatality rate to the difference in pedestrian death rate was estimated as follows using Formula 3:

$$RC_{walking\ exposure}=\frac{|\ln(182.5/183.4)|}{|\ln(182.5/183.4)|+|\ln(1.37/1.15)|+|\ln(8.14/4.12)|}\times 100\%=1\%$$
$$RC_{collision\ risk}=\frac{|\ln(1.37/1.15)|}{|\ln(182.5/183.4)|+|\ln(1.37/1.15)|+|\ln(8.14/4.12)|}\times 100\%=20\%$$
$$RC_{collision\ case\ fatalityrate}=\frac{|\ln(8.14/4.12)|}{|\ln(182.5/183.4)|+|\ln(1.37/1.15)|+|\ln(8.14/4.12)|}\times 100\%=79\%$$

We considered age as a potential effect modifier and conducted subgroup analyses for ages (5–15, 16–24, 25–64, and 65 and over). Since we found little difference by age, we do not present these results.

DISCUSSION

This study explored three factors (walking exposure, collision risk, and collision case fatality rate) to explain why every year male pedestrians were approximately 2.3 times as likely to die as female pedestrians. The single largest contributor was collision case fatality rate, which explained 79% of the difference between sexes. Collision risk accounted for 20%, while differences in walking exposure contributed only 1%.

We found that male pedestrians were twice as likely to die when involved in vehicle-pedestrian collisions as female pedestrians. Other studies have also reported higher collision case fatality rates among males, but with weaker associations. An analysis of 1997–2006 FARS and GES data reported that the collision case fatality rate was approximately 40% higher among males.[21] A study of 552 collisions from 1994 through 1998 in six metropolitan areas in the U.S. reported that the percentage of pedestrians who died as a result of vehicle-pedestrian collisions was 18% among males and 12% among females.[22] Using 6,965 patients admitted to a trauma center in Los Angeles, Starnes et al reported that the proportion dying was 7.3% among males and 8.0% among females.[23] Starnes' result is different from ours because their patients were severely injured pedestrians treated at a major trauma center, and excluded deaths at the scene that were not brought to hospital. Our cases were a probability sample of all pedestrians and all injury severities involved in collisions.

A major strength of our study was that in addition to collision data we had walking exposure information, which allowed us to simultaneously assess the relative contributions of three components: walking exposure, collision risk, and collision case fatality rate. This method dissects the broad measure of pedestrian death rate per person-years and assigns factors with their relative importance. This might permit prevention to be targeted at the factors that have significant effects on elevated pedestrian deaths among males. Similar national travel surveys for exposure data are conducted annually in the United Kingdom,[8, 24] and exposure data is also available in other countries such as Germany, The Netherlands, Norway, Spain, Sweden, and Switzerland.[25, 26] More research can be conducted in other countries to confirm the U.S. findings and identify factors amenable to intervention.

There were several limitations in our study. 1) GES does not include crashes never reported to the police; however, these are the property damage only crashes and crashes resulting in minor injuries and the under-reporting would be similar according to gender.[27] 2) NHTS reported walking on trips of about 0.5 kilometer daily, which may be an underestimate as respondents tend to report only trips they consider transportation related..[16, 28] 3)The walking exposure was estimated from the NHTS, which was subject to sampling variation and possible limited representativeness of a landline-only phone survey.[16, 28] Sampling weights in NHTS were adjusted for nonresponse, undercoverage, and multiple phones in a household.[16, 28] However, they did not adjust for cell-phone-only households which are rapidly growing in number (18.4% in July-December, 2008 when our data were collected and almost 32% in 2011).[29, 30] The 2008–2009 NHTS survey included a small pilot sample of 1,254 cell-phone-only households, but did not include them in the final dataset.[16] Despite these limitations, the NHTS estimate is the only available information in the U.S. on walking and other transport exposure data.[16, 31, 32] 4) Dead pedestrians in FARS might not be well represented in the NHTS exposure survey of live residents. However the percent of the population that dies as pedestrians each year is very small and pedestrian who die in one year would have been represented in exposure data for earlier times. 5) Our estimates of relative contribution of each component were point estimates only and methods have not been developed to estimate confidence intervals.

Current proven strategies to reduce pedestrian fatalities in both men and women include speed controls in areas where the risk to pedestrians is high. For example the implementation of 32 kilometers (20 miles) per hour speed zones was associated with a 30% reduction in pedestrian injuries in London.[33] Other strategies, such as improved vehicle designs that better protect pedestrians in a collision are likely to result in even greater reductions in pedestrian deaths. [2, 34–36] However given our finding that male pedestrians were twice as likely to die when involved in vehicle-pedestrian collisions as female pedestrians, more research is needed to uncover the reasons for this male excess. More detailed studies are needed to examine whether the pedestrian behaviors, vehicle and driver factors, and environmental situations differ by sex, given that they are involved in collisions. Pedestrian behaviors might include alcohol use, drug involvement, distraction factors such as cell phone use. Vehicle factors might include impact speed, and vehicle mass (passenger cars, truck, or bus). Driver factors might include alcohol use, drug involvement, and distraction factors. Environmental situations might include time of collision, and emergency medical service response time. Better understanding of the reasons why males are more likely to die in pedestrian collisions is likely to lead to improving the spectrum of interventions available to reduce pedestrian fatalities.

CONCLUSIONS

The majority of the male-female discrepancy in pedestrian death rates in the U.S. results largely from differences in collision case fatality rates. Better understanding of the reasons for the excess fatality risk in males is likely to lead to increased strategies to prevent pedestrian fatalities.

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What this paper adds

What is already known on this subject

- Males are overrepresented in pedestrian deaths worldwide.
- No previous studies have simultaneously assessed walking exposure, collision risk, and collision case fatality rate to explain the male-female discrepancy in pedestrian death rate.

What this study adds

- The walking exposure is similar between sexes in the U.S.
- The collision risk is slightly higher among males than females.
- The elevated pedestrian deaths among males mainly results from their high case fatality rate when involved in vehicle-pedestrian collisions, compared with females.

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Table 1

Pedestrian deaths, collisions, walking exposure and residents, by sex, United States, 2008–2009

Sex	No. of deaths	No. of collisions	No. of kilometers walked (Millions)	No. of residents (Millions)
Male	2,855	35,084	25,531	139.9
Female	1,259	30,559	26,509	144.6

*The calculations are annual basis.

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Table 2

Pedestrian death rate, walking exposure, collision risk, and collision case fatality rate, by sex, United States, 2008–2009

Sex	Pedestrian death rate per 100,000 person-years	No. of kilometers per person-year	Collision rate per million kilometers	Fatality rate per 100 collisions
Male	2.04	182.5	1.37	8.14
Female	0.87	183.4	1.15	4.12
Ratio (male vs female)	2.34	0.995	1.191	1.976