



Revisiting exposure: Fatal and non-fatal traffic injury risk across different populations of travelers in Wisconsin, 2001–2009

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ABSTRACT

Comparing the injury risk of different travel modes requires using a travel-based measure of exposure. In this study we quantify injury risk by travel mode, age, race/ethnicity, sex, and injury severity using three different travel-based exposure measures (person-trips, person-minutes of travel, and person-miles of travel) to learn how these metrics affect the characterization of risk across populations. We used a linked database of hospital and police records to identify non-fatal injuries (2001–2009), the Fatality Analysis Reporting System for fatalities (2001–2009), and the 2001 Wisconsin Add-On to the National Household Travel Survey for exposure measures. In Wisconsin, bicyclists and pedestrians have a moderately higher injury risk compared to motor vehicle occupants (adjusting for demographic factors), but the risk is much higher when exposure is measured in distance. Although the analysis did not control for socio-economic status (a likely confounder) it showed that American Indian and Black travelers in Wisconsin face higher transportation injury risk than White travelers (adjusting for sex and travel mode), across all three measures of exposure. Working with multiple metrics to form comprehensive injury risk profiles such as this one can inform decision making about how to prioritize investments in transportation injury prevention.

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1. Introduction

Traffic-related injuries were the leading cause of death for people ages five to 34 in the United States in recent years (CDC, 2013). From 2005 to 2010, unintentional injuries involving motor vehicle traffic accounted for either the highest or second-highest proportion of injury deaths for people in every age category (CDC, 2013).

Travel is essential for carrying out life's activities, and all populations are exposed to traffic-related hazards. Yet, because people travel differently, and in different environments, our exposure to traffic hazards may vary. A comprehensive, multi-dimensional understanding of road transportation safety needs to account for heterogeneity in injury risk, including travel experiences of men and women, people at different stages of the life course, and travelers in different geographic areas, as well as travel by various modes (e.g., automobile, train, bicycle).

Several different exposure measures have been used in road safety research and policy, and each one offers a different perspective on the risk of travel. Such measures have included population, driving distance, driving time, traffic volume, number of registered vehicles, number of licensed drivers, and gasoline consumption (Carroll, 1973). In reality, the selection of exposure measures is constrained by the availability and quality of data (Naci et al., 2009). Most often, information about exposure is collected through administrative processes, though occasionally researchers and agencies have conducted surveys with the specific aim of measuring populations' exposure to traffic hazards (Chipman et al., 1992).

One of the limitations of previous research about travel risk is that it has focused primarily on motor vehicle travel (Chipman et al., 1993; Kweon and Kockelman, 2003). Only a small number of studies have compared the risk of different travel modes (Beck et al., 2007; McAndrews, 2011). This question of how best to measure exposure when comparing different travel modes is relevant because current public health and transportation policy agendas promote increasing walking and bicycling. For example, walking and bicycling may seem safe compared to driving when measured per minute of travel time, yet because the average distance of a walk or bike trip is generally shorter than one made by a car, the

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injury rate per mile traveled may show that walking and bicycling are relatively high-risk modes. The question arises: How should we evaluate the relative risk across modes, and are some measures better than others for certain problems?

A second limitation of the literature on travel risk is the lack of information about race and ethnicity. One reason for this omission is that crash victims' race and ethnicity were not included in the national database of traffic deaths, the Fatality Analysis Reporting System (FARS), until 1999 (Briggs et al., 2006). The majority of studies about traffic-related injuries for specific racial and ethnic groups analyzed injury rates using population-based measures of exposure (Campos-Outcalt et al., 1997, 2002, 2003; CDC, 1991; Gallaher et al., 1992; Harper et al., 2000; Schiff and Becker, 1996; Sewell et al., 1989). Only one study (Braver, 2003) has analyzed transportation injury risk by race and ethnicity using travel-based measures of exposure. Braver (2003) also included information about the socioeconomic status (SES) of victims, but the study was limited to adult motor vehicle occupants. When adjusting for SES, Braver found that Black and Hispanic adult men have higher death rates per trip as motor vehicle occupants relative to Whites, and that low SES was a stronger determinant of motor vehicle occupant death than race and ethnicity (Braver, 2003).

To better understand transportation injury risk, we combine information about three different dimensions of the problem: (1) the selection of metrics; (2) differences in risk by demographic factors and travel mode; and (3) different types of injury severity. With respect to metrics, we examined how three different travel-based exposure measures (person-trips, person-minutes of travel, and person-miles of travel) and a population-based exposure measure affect the characterization of transportation injury risk by travel mode, age, race/ethnicity, sex, and injury severity. For each measure of exposure, we present crude and adjusted fatal, inpatient, and emergency department injury rates for Wisconsin (2001–2009 for inpatient and fatal injuries, and 2004–2009 for injuries treated in emergency departments) using a comprehensive database of linked hospital–police records, which is the best available data for non-fatal transportation injuries. With respect to differences in risk by travel mode and demographic factors, this study shows that in Wisconsin, pedestrians and bicyclists generally have higher injury risk across all three travel-based metrics, and the distance-based measure of exposure accentuates the magnitude of the risk. The study also contributes new evidence that Native American and Black travelers in Wisconsin face higher traffic-related injury risk, controlling for sex and travel mode. Considering both fatal and non-fatal injuries creates a more comprehensive analysis and reveals the significant burden of transportation injury beyond fatalities.

Creating a profile of population-level transportation injury risk can be used to prioritize investment in injury prevention.

2. Materials and methods

2.1. Study area

This study focuses on transportation injury risk for the state of Wisconsin in the United States. Wisconsin's population in 2012 was about 5.7 million (the median population for states in the US was 4.4 million in 2012). Wisconsin's economy and transportation system have been influenced by agriculture and manufacturing. Its settlement patterns include smaller cities, low-density suburbs, rural areas, and the large metropolitan region of Milwaukee. Personal travel occurs mainly by automobile, though there are communities in which walking and bicycling are important modes for both utilitarian travel and recreation. Bus ridership in the state's major cities is relatively high for their size and population density.

2.2. Injury and fatality data

This study uses two sources of information about fatal and non-fatal injuries: hospital records and police-reported traffic fatalities. Fatal and inpatient injury data sets cover the period 2001–2009, and emergency department data cover only 2004–2009. Fatal, inpatient, and emergency department data are mutually exclusive. Victims who were treated in an emergency department and as an inpatient are counted as inpatients. Victims who died within 30 days of the crash are counted as fatalities.

Wisconsin participates in the Crash Outcome Data Evaluation System (CODES) program sponsored by the National Highway Traffic Safety Administration (NHTSA). CODES is a linked data set that combines hospitals' inpatient and emergency department records with police-reported crashes. As of 2009, 16 states participated in the program (NHTSA, 2009).

The official CODES data set for Wisconsin does not include the race and ethnicity variables that exist in the original hospital records. Thus, on our request, the Center for Health Research Systems and Analysis (CHSRA) created an alternative version of CODES using the original hospital data (acquired through the Healthcare Cost and Utilization Project (HCUP)) and the CODES probabilistic matching methodology (NHTSA, 1996; Bigelow et al., 1999).

In the analysis of non-fatal injuries by race and ethnicity we include only inpatient records because information about race and ethnicity was missing from 45.2% of emergency department observations, whereas only 2.7% of the inpatient injury observations lacked information about race and ethnicity.

FARS provided information about fatal injuries as well as the relevant demographic information about victims.

2.3. Travel and exposure data

We use the Wisconsin Add-On Sample to the 2001 National Household Travel Survey to construct travel-based measures of exposure. This survey uses random digit dialing to reach households, and every member of a participating household completes a two-day activity diary providing detailed information about their travel (in 2001, children age 0–4 years were included).

The 2001 Wisconsin Add-On Survey has an un-weighted sample of about 17,000 households and 160,000 daily unlinked person-trips. (For example, if a person takes two buses to get from home to work, that journey counts as two unlinked trips, yet is only one linked trip.) The survey responses are weighted to account for population estimates and non-response (Proussaloglou et al., 2004). Sources of non-sampling error in the travel survey include undercoverage of households by income, race, Hispanic origin, and household tenure. The undercoverage problem is larger for non-White respondents. This is partially corrected by the survey weighting, but the true variation in travel by certain populations is not known.

The person-trips by mode in our analysis include all weighted unlinked trips as well as weighted transit access and egress trips. We also use information about each trip's duration and distance, although survey participants do not always reliably recall these details and measures based on trip duration and distance are less reliable than measures using only trips (McGuckin, 2012; Scholssberg et al., 2007).

We make two assumptions in our use of these data. First, we assume that travel behavior across travel modes and populations in 2001 is similar enough to travel in every year through 2009 to make the estimates comparable. In Wisconsin, vehicle-miles of travel on all roads was 57.3 billion in 2001 and 58.2 billion in 2009, reaching a peak of 60.4 billion in 2004 (Wisconsin Department of Transportation, 2012). According to the 2009 version of the Wisconsin Add-On to the NHTS, the number of motor vehicle trips in

the 2009 was 6% lower than the estimate for 2001. Estimates of walk, bike, and motorcycle trips from the 2009 travel survey illustrate the greater variability and uncertainty in measuring travel by these modes. The number of motorcycle trips estimated in the 2009 survey was 118% higher than in 2001. The number of walk trips was 40% higher than in 2001, and the number of bicycle trips was 16% lower than in the 2001. Our analysis accounts for the sampling uncertainty in the 2001 survey estimates, but does not capture changes in travel patterns over time. Using the 2009 travel survey was not an option because its smaller sample size (about 1700 households) did not allow for sufficient disaggregation to analyze injury risk by demographic factors and travel mode. There were not any major changes in travel patterns by sex, age, and race/ethnicity between the two surveys.

We make a second assumption about race and ethnicity. Because information about race and ethnicity was collected only for one member of each surveyed household, we assume that that every other respondent from that household has the same race and ethnicity.

Wisconsin Department of Health Services provided annual population estimates used to calculate population rates.

2.4. Statistical methods

We coded victims and trips with the following travel modes: motor vehicle occupant, bicyclist (including “other cyclist”), bus occupant (includes school and other buses), motorcyclist, pedestrian (including “personal conveyances”), and other/unknown. We do not report rail transit injuries and fatalities because these were not identifiable in all data sets, nor do we report bus occupant injury rates because these events were extremely rare during the study period (12 fatalities and 44 inpatient injuries over nine years; zero emergency department injuries over six years). We coded Hispanic ethnicity to include individuals identified as Mexican, Puerto Rican, Cuban, Central/South American, and European Spanish. We coded Asian to include individuals identified as Chinese, Japanese, Hawaiian, Filipino, Asian Indian, Korean, Samoan, Vietnamese, Guamanian, and Other Pacific Islander. The categories White, Black, American Indian, and Asian do not include individuals who identify as Hispanic. We do not report injury rates for the “other/unknown” and “multiracial” categories because we do not know what definitions of other, unknown, and multiracial were used across the various data sets.

2.4.1. Crude injury rates per 100,000 population

We calculated crude average annual fatal, inpatient, and emergency department injury rates per 100,000 population by summing the injuries over 2001–2009 and dividing by the sum of the Wisconsin population for that same period (for emergency department injuries we sum over 2004–2009). We computed 95% confidence intervals for the incidence rates based on the gamma distribution (Fay and Feuer, 1997; Kochanek et al., 2004) because this method is appropriate for small numbers of injury events (under 100 per year), and it does not bias results when the number of events is larger. The confidence intervals for population-based rates do not account for any sampling variation that may exist in the population estimates.

2.4.2. Crude injury rates per unit of travel

We calculated crude average annual fatal, inpatient, and emergency department injury rates per 100 million person-trips, per one billion person-minutes, and per one billion person-miles for 2001–2009, with 95% confidence intervals based on the gamma distribution. In contrast to the population-based incidence rates, the confidence intervals for travel-based rates account for sampling variation in the travel estimates using the first-order Taylor

series approximation for the variance of the ratio of two random variables (Beck et al., 2007). As in Beck et al. (2007), the variance of the rate $\text{var}(r)$ was calculated as $\text{var}(r) = (1/x^2) \times [\text{var}(y) + r^2\text{var}(x)]$, where $r = y/x$. This means that the confidence intervals reflect the year-to-year uncertainty in the number of injury events and uncertainty introduced by the sample of the travel survey. The standard errors of travel measures (person-trips, person-minutes, and person-miles) were computed using the replicate survey weights included in the NHTS data set.

2.4.3. Age, sex, and race/ethnicity adjusted injury rates per unit of travel

We calculated adjusted injury rates per person-trip, person-minutes, and person-miles by travel mode using direct standardization (Szklo and Nieto, 2004). We could not simultaneously standardize by age, sex, and race/ethnicity across all of the travel modes because of small numbers of events at that level of disaggregation. Thus, we calculated separately the sex and race/ethnicity-adjusted rates and age and race/ethnicity adjusted rates (rates by race/ethnicity for inpatient injuries only).

To calculate the age and sex adjusted rates, we first computed the age and sex-specific injury rates and then weighted them based on a reference population. Because we are using travel-based measures of exposure instead of population, our reference “population” was the travel mode share for each corresponding age–sex category in the 2001 national sample of the NHTS.

The variance of the adjusted rates was calculated as the sum of the strata variances times their squared weight. Again, we used the first-order Taylor series approximation for the variance of the ratio of two random variables to account for sampling variation in the travel estimates. Confidence intervals for the adjusted rates are based on the gamma distribution (Fay and Feuer, 1997). We calculated the variance of the standardized rate ratios following Flanders (1984). Confidence intervals for the standardized rate ratios are based on the inverse F distribution following Fay (1999).

All computation was carried out in SAS 9.3.

3. Results

3.1. Population-based measures of exposure

For the period 2001–2009, the total number of traffic-related fatalities and inpatient injuries in Wisconsin were 6667 and 32,335 respectively. The total traffic-related emergency department injuries were 162,598 for 2004–2009. (see Table 1) The average annual fatal, inpatient, and emergency department injuries were 740, 3593, and 27,100 respectively. Motor vehicle occupants accounted for the largest share of fatalities (79%), inpatient injuries (74%), and emergency department injuries (90%). Motorcyclists accounted for the second-largest share of traffic-related fatalities (13%), inpatient injuries (16%), and emergency department injuries (5%).

The population of Wisconsin is divided roughly equally between men and women, though men accounted for 68% of traffic-related fatalities and 61% of traffic-related inpatient injuries. Women accounted for more emergency department injuries (53%) than men (47%). Relative to their population, children accounted for a small share of traffic-related injuries, whereas adolescents accounted for a relatively large share. White travelers experienced the vast majority of traffic-related injuries, and these were roughly in proportion to their population.

These descriptive measures indicate that in Wisconsin traffic injury primarily affects adult, White, male motor vehicle occupants. However, of all the racial and ethnic groups, American Indians had the highest traffic-related fatal and inpatient injury rates per

Table 1
Crude traffic injury rates per 100,000 population, by person characteristics and travel mode, Wisconsin, 2001–2009.

Person characteristics, travel mode	Average annual population ^a		Fatal ^b		Inpatient ^b		Emergency department ^c		Crude injury rate per 100,000 population (95% CI)		
	N	%	Number	%	Number	%	Number	%	Fatal	Inpatient	Emergency department
Motor vehicle	–	–	5232	78.5	24,055	74.4	145,748	89.6	10.4 (9.3, 11.6)	48.0 (44.1, 52.1)	432.2 (386.6, 480.3)
Motorcycle	–	–	865	13.0	5126	15.9	8095	5.0	1.7 (1.6, 1.9)	10.2 (8.8, 11.8)	24.0 (22.4, 25.7)
Walk	–	–	458	6.9	2348	7.3	5351	3.3	0.9 (0.8, 1.0)	4.7 (4.2, 5.2)	15.9 (14.9, 16.9)
Bicycle	–	–	92	1.4	762	2.4	3404	2.1	0.2 (0.2, 0.2)	1.5 (1.3, 1.8)	10.1 (9.4, 10.8)
Bus	–	–	12	0.2	44	0.1	0	0.0	–	–	–
Male	2,759,663	49.6	4529	67.9	19,781	61.2	75,914	46.7	18.2 (16.6, 19.9)	79.6 (74.2, 85.3)	453.6 (406.7, 503.1)
Female	2,807,705	50.4	2138	32.1	12,533	38.8	86,587	53.3	8.5 (7.6, 9.4)	49.6 (45.2, 54.2)	509.8 (462.1, 559.8)
Age 0–4	140,547	2.5	62	0.9	310	1.0	1848	1.1	2.0 (1.6, 2.4)	9.9 (8.2, 11.7)	87.0 (74.6, 100.3)
Age 5–14	736,609	13.2	196	2.9	1431	4.4	9050	5.6	3.0 (2.5, 3.5)	21.6 (18.5, 24.9)	208.2 (182.7, 235.3)
Age 15–24	808,970	14.5	1822	27.3	8141	25.2	51,617	31.7	25.0 (21.9, 28.4)	111.8 (101.0, 123.2)	1059.2 (932.9, 1193.4)
Age 25–64	2,748,223	49.4	3519	52.8	17,759	54.9	89,244	54.9	13.3 (12.2, 14.4)	67.1 (62.3, 72.0)	497.6 (457.6, 539.4)
Age 65+	730,376	13.1	1068	16.0	4694	14.5	10,839	6.7	16.2 (14.7, 17.8)	71.4 (66.2, 76.9)	244.1 (220.2, 269.1)
American Indian	51,612	0.9	149	2.2	399	1.2	–	–	32.1 (26.1, 38.7)	85.9 (78.1, 94.0)	–
Asian	114,621	2.1	77	1.2	332	1.0	–	–	7.5 (4.9, 10.6)	32.2 (25.4, 39.8)	–
Black	334,699	6.0	286	4.3	2147	6.6	–	–	9.5 (8.1, 11.0)	71.3 (64.8, 78.1)	–
Hispanic	251,415	4.5	293	4.4	1142	3.5	–	–	12.9 (10.4, 15.8)	50.5 (44.8, 56.5)	–
White	4,815,021	86.5	5766	86.5	27,077	83.7	–	–	13.3 (12.1, 14.6)	62.5 (57.6, 67.6)	–
Total	5,567,369	100.0	6667	100.0	32,335	100.0	162,598	100.0	13.3 (12.1, 14.6)	64.5 (59.7, 69.6)	482.2 (434.8, 532.0)

Notes:

^a Average annual population for 2001–2009.

^b Fatal and inpatient injury totals for 2001–2009.

^c Emergency department totals for 2004–2009 only.

Table 2
Summary of travel patterns by person characteristics and travel mode, Wisconsin 2001.

Population or mode	Person-trips		Person-minutes		Person-miles		Average minutes per trip	Average miles per trip
	(Million)	%	(Million)	%	(Million)	%		
Motor vehicle	6474	89.1	116,155	86.6	70,682	96.0	17.9	10.9
Motorcycle	11	0.2	256	0.2	154	0.2	23.2	14.0
Walk	490	6.7	9265	6.9	623	0.8	18.9	1.3
Bicycle	86	1.2	1991	1.5	176	0.2	23.2	2.0
Bus	167	2.3	5517	4.1	1699	2.3	33.0	10.2
Male	3556	49.0	69,634	51.9	39,012	53.0	19.6	11.0
Female	3708	51.0	64,490	48.1	34,622	47.0	17.4	9.3
Age 0–4	354	4.9	5680	4.4	3210	4.5	16.0	9.1
Age 5–14	910	12.5	16,104	12.4	6943	9.7	17.7	7.6
Age 15–24	962	13.2	17,916	13.7	9922	13.9	18.6	10.3
Age 25–64	4257	58.6	79,776	58.2	46,488	61.9	18.7	10.9
Age 65+	781	10.8	14,648	11.3	7071	9.9	18.8	9.1
American Indian	43	0.6	821	0.6	425	0.6	19.1	9.9
Asian	104	1.4	1938	1.5	894	1.2	18.6	8.6
Black	249	3.4	6289	4.7	3407	4.6	25.3	13.7
Hispanic	314	4.3	5932	4.6	2768	3.8	18.9	8.8
White	6436	88.6	117,242	90.8	64,992	88.3	18.2	10.1
Total	7264	100.0	134,124	100.0	73,633	100.0	18.5	10.1

Note: Person-trips, person-minutes, and person-miles are weighted, unlinked trips and include access and egress trips to transit.

100,000 population (32.3 and 85.9, respectively), and Blacks had the second-highest inpatient injury rates per 100,000 population (71.2). Asians had the lowest rates for both fatal and non-fatal injuries.

3.2. Travel-based measures of exposure

Motor vehicle trips comprised the greatest share of travel, at 89% of all person-trips, 87% of person-minutes, and 96% of all person-miles. (see Table 2) Motorcyclists accounted for the smallest share of travel by each of the three measures. Walking accounted for about 7% of person-trips and person-minutes of travel, but only 0.8% of person-miles of travel.

Though there is some variation in the average trip duration by mode, the greatest amount of variation is with respect to trip distance. An average walk trip is 1.3 miles and the average bicycle trip is 2.0 miles, whereas the average bus, car, and motorcycle trips are all over 10 miles. Men make somewhat longer trips than women, and adults and adolescents travel somewhat farther than children.

Among the racial and ethnic groups, Black travelers make the longest trips by time and distance. According to the 2001 Wisconsin Add-On, travel mode shares for Blacks in Wisconsin were 78% motor vehicle, 17% walk, 4% transit, and <1% bicycle, whereas the travel mode shares for Whites were 90% motor vehicle, 6% walk, 2% transit, and 1% bike. About 70% of Wisconsin's African American population lives in Milwaukee County, and in Milwaukee County only 68% of African American households have access to a private vehicle, and only about 60% of African Americans have a driver's license. (Southeastern Wisconsin Regional Planning Commission, 2006: 576; Wisconsin Department of Health Services, 2013)

3.2.1. Crude injury rates per unit of travel

Traffic-related injury rates per person-trip, person-minutes of travel, and person-miles of travel reflect travel risk in contrast to the overall societal risk that a population-based rate expresses.

Motorcyclists have the highest travel risk across all three measures of exposure (e.g., 841 fatalities per 100 million person-trips, 4981 inpatient injuries per 100 million person-trips, and 11,800 emergency department injuries per 100 million person-trips). (Table 3) Fatality rates for bicyclists and pedestrians are slightly higher than those for motor vehicle occupants when measured per trip and per person-minute of travel, but walking and

bicycling have much higher fatality rates than motor vehicle occupants when measured by person-miles of travel. Inpatient and emergency department injury rates per 100 million person-trips for bicyclists are about two times higher than those for motor vehicle occupants.

With respect to demographic characteristics, men face higher travel risk than women across all three measures of exposure and for both fatal and hospitalized injuries, but women have higher rates of emergency department injuries across all three measures of exposure. Children have lower travel risk than adults, and adolescents have the highest travel risk across all three measures of exposure and across all three severity types of traffic-related injuries. Older travelers have relatively high travel risk across all three measures of exposure compared to adults ages 25–64 for both fatal and hospitalized injuries, but not for traffic related injuries treated in emergency departments.

Across the different racial and ethnic groups, American Indian travelers have the highest traffic fatality and hospitalized injury rates across all three travel-based measures of exposure. The traffic-related hospitalized injury rate per 100 million trips for blacks is nearly as high as that of American Indians.

The average ratio of inpatient injuries to fatalities is about 5:1, but a few categories of travelers have a different pattern. Bicyclists have a higher inpatient injury/fatality ratio (8.3), as do children age 5–14 (7.2), and blacks (7.5); American Indians have a relatively low ratio of inpatient injuries to fatalities (2.7).

3.2.2. Standardized rates and standardized rate ratios per unit of travel

Table 4 presents adjusted traffic-related fatal, inpatient, and emergency department injury rates by person-trip, person-minutes of travel, and person-miles of travel. Mode-specific rates were adjusted for sex and age. Sex-specific rates were adjusted for mode and age. Age-specific rates were adjusted for mode and sex. Table 5 presents rates adjusted for race and ethnicity. Mode-specific rates were adjusted for sex and race/ethnicity. Sex-specific rates were adjusted for mode and race/ethnicity. Age-specific rates were adjusted for mode and race/ethnicity.

Tables 6 and 7 present adjusted rate ratios. The ratio of motorcyclist fatalities and injuries to those of motor vehicle occupants is about 90:1 when adjusted for sex and age, whereas the ratio for injuries treated in the emergency department is about 30:1.

Table 3
Average annual crude traffic injury rates per person-trip, person-minutes, and person-miles, by person characteristics and travel mode, Wisconsin, 2001–2009.

Person characteristics, travel mode	Fatal injury rate and 95% CI			Inpatient injury rate and 95% CI			Emergency department injury rate and 95% CI		
	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles
Motor vehicle	9.0 (8.1, 9.9)	5.0 (4.5, 5.5)	8.2 (7.4, 9.1)	41.3 (38.2, 44.5)	23.0 (21.3, 24.8)	37.8 (35.0, 40.1)	375.2 (338.2, 414.1)	209.1 (188.5, 230.8)	343.7 (309.8, 379.3)
Motorcycle	840.6 (757.8, 927.6)	375.9 (338.9, 414.8)	622.4 (561.1, 686.9)	4981.4 (4248.0, 5772.3)	2227.4 (1899.5, 2581.1)	3688.4 (3145.2, 4274.2)	11,800.0 (10,996.0, 12,632.0)	6276.4 (4916.6, 5648.6)	8737.0 (8140.7, 9354.1)
Walk	10.4 (9.6, 11.2)	5.5 (5.1, 6.0)	81.7 (75.2, 88.5)	53.2 (47.2, 59.6)	28.2 (25.0, 31.5)	419.0 (371.6, 469.1)	181.9 (171.3, 192.7)	96.3 (90.7, 102.0)	1432.1 (1349.0, 1517.6)
Bicycle	11.9 (10.0, 13.9)	5.1 (4.3, 6.0)	58.2 (49.2, 68.1)	98.2 (82.4, 115.5)	42.5 (35.7, 50.0)	482.4 (404.5, 567.0)	658.3 (617.3, 700.5)	285.0 (267.2, 303.3)	3232.4 (3,031.3, 3,439.9)
Male	14.2 (13.0, 15.4)	7.2 (6.6, 7.8)	12.9 (11.8, 14.0)	61.8 (57.7, 66.1)	31.6 (29.4, 33.7)	56.3 (52.6, 60.2)	355.8 (321.7, 391.6)	181.7 (164.3, 200.0)	324.3 (293.2, 357.0)
Female	6.4 (5.8, 7.1)	3.7 (3.3, 4.1)	6.9 (6.2, 7.6)	37.6 (34.3, 41.0)	21.6 (19.7, 23.1)	40.2 (36.7, 43.9)	389.2 (355.1, 424.8)	223.8 (204.2, 244.3)	416.8 (380.3, 455.0)
Age 0–4	1.9 (1.6, 2.4)	1.2 (1.0, 1.5)	2.1 (1.7, 2.6)	9.7 (8.2, 11.4)	6.1 (5.1, 7.1)	10.7 (9.1, 12.6)	87.0 (76.3, 98.4)	54.2 (47.5, 61.3)	96.0 (84.1, 108.6)
Age 5–14	2.4 (2.0, 2.8)	1.4 (1.1, 1.6)	3.1 (2.6, 3.7)	17.5 (14.9, 20.3)	9.9 (8.4, 11.5)	22.9 (19.5, 26.6)	165.7 (144.9, 187.9)	93.7 (81.9, 106.2)	217.3 (190.0, 246.3)
Age 15–24	21.1 (18.4, 23.9)	11.3 (9.9, 12.8)	20.4 (17.8, 23.1)	94.1 (85.0, 103.6)	50.5 (45.6, 55.6)	91.2 (82.3, 100.4)	894.7 (785.6, 1010.8)	480.2 (421.6, 542.5)	867.0 (761.3, 979.6)
Age 25–64	9.2 (8.5, 9.9)	4.9 (4.5, 5.3)	8.4 (7.8, 9.0)	46.3 (42.9, 49.9)	24.7 (22.9, 26.6)	42.4 (39.3, 45.7)	349.4 (323.5, 376.2)	186.4 (172.7, 200.8)	320.0 (296.3, 344.5)
Age 65+	15.2 (14.0, 16.5)	8.1 (7.4, 8.8)	16.8 (15.4, 18.2)	66.8 (62.5, 71.3)	35.6 (33.3, 38.0)	73.8 (69.0, 78.7)	231.4 (212.9, 250.8)	123.3 (113.4, 133.6)	255.5 (235.0, 276.8)
American Indian	38.1 (31.7, 45.1)	20.2 (16.8, 23.9)	38.9 (32.4, 46.1)	102.1 (92.3, 112.4)	54.0 (48.8, 59.5)	104.3 (94.3, 114.8)	–	–	–
Asian	8.3 (5.3, 11.9)	4.4 (2.8, 6.4)	9.6 (6.1, 13.8)	35.6 (28.2, 43.9)	19.0 (15.1, 23.5)	41.2 (32.6, 50.9)	–	–	–
Black	12.7 (10.8, 14.9)	5.1 (4.3, 5.9)	9.3 (7.9, 10.9)	95.7 (86.4, 105.4)	37.9 (34.3, 41.8)	70.0 (63.2, 77.2)	–	–	–
Hispanic	10.4 (8.5, 12.4)	5.5 (4.5, 6.6)	11.8 (9.6, 14.1)	40.3 (35.5, 45.5)	21.4 (18.8, 24.1)	45.8 (40.3, 51.7)	–	–	–
White	10.0 (9.1, 10.9)	5.5 (5.0, 6.0)	9.9 (9.0, 10.8)	46.7 (43.1, 50.5)	25.7 (23.7, 27.7)	46.3 (42.7, 50.0)	–	–	–
Total	10.2 (9.3, 11.1)	5.5 (5.1, 6.0)	10.1 (9.2, 10.9)	49.5 (45.8, 53.2)	26.8 (24.8, 28.8)	48.8 (45.2, 52.5)	373.1 (339.0, 408.0)	202.0 (183.6, 221.4)	368.0 (334.4, 403.3)

Notes: Emergency department injury rates are for 2004–2009 only.

Table 4
Average annual adjusted traffic injury rates per person-trip, person-minutes, and person-miles, standardized for age, sex, and travel mode, Wisconsin, 2001–2009.

Person characteristic, mode	Fatal injury rate and 95% CI			Inpatient injury rate and 95% CI			Emergency department injury rate and 95% CI		
	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles
Motor vehicle	8.8 (7.7, 10.0)	4.9 (4.3, 5.5)	8.0 (7.0, 9.0)	40.6 (37.2, 44.2)	22.5 (20.6, 24.5)	36.8 (33.7, 40.0)	371.5 (334.2, 410.9)	206.7 (186.1, 228.5)	336.7 (303.2, 372.1)
Motorcycle	803.2 (670.7, 961.1)	380.7 (307.8, 471.0)	717.6 (556.1, 926.1)	4634.1 (3884.3, 5464.7)	2143.1 (1781.7, 2548.8)	3768.7 (3099.1, 4536.4)	10,938.3 (10,043.3, 11,874.1)	5091.3 (4665.2, 5536.9)	9167.1 (8385.9, 9985.3)
Walk	10.2 (8.1, 12.9)	5.3 (4.2, 6.7)	88.0 (71.7, 10.8)	52.7 (43.5, 62.8)	27.8 (22.9, 33.2)	433.9 (356.1, 520.0)	179.3 (162.4, 197.1)	96.5 (87.5, 105.9)	1424.9 (1297.6, 1559.3)
Bicycle	17.9 (9.9, 29.5)	6.9 (3.8, 11.4)	84.0 (46.7, 138.1)	127.0 (92.3, 168.5)	52.7 (38.4, 69.8)	628.7 (459.3, 829.3)	685.6 (604.2, 774.1)	302.1 (266.9, 340.1)	3435.4 (3039.9, 3861.0)
Male	13.8 (12.0, 15.9)	7.5 (6.5, 8.8)	14.6 (12.4, 17.2)	60.0 (53.6, 66.9)	33.0 (29.3, 37.0)	63.2 (55.6, 71.6)	344.9 (308.4, 383.6)	181.1 (162.1, 201.1)	334.3 (299.7, 370.8)
Female	6.3 (5.3, 7.7)	3.7 (3.1, 5.4)	7.4 (6.1, 8.9)	36.9 (32.7, 41.5)	22.0 (19.5, 24.8)	43.2 (38.2, 48.6)	380.5 (344.8, 418.2)	221.0 (200.3, 242.8)	428.3 (388.4, 470.3)
Age 0–4	2.1 (1.3, 3.2)	1.4 (0.9, 2.1)	3.1 (1.8, 5.0)	11.5 (8.5, 15.1)	7.5 (5.5, 9.9)	19.6 (14.2, 26.0)	89.2 (76.4, 103.1)	56.0 (48.1, 64.6)	116.7 (100.0, 134.8)
Age 5–14	2.8 (1.8, 4.3)	2.2 (1.2, 3.7)	6.6 (3.4, 11.5)	18.3 (14.7, 22.5)	11.5 (8.8, 14.8)	28.2 (20.7, 37.8)	165.2 (143.1, 188.9)	99.1 (85.8, 113.4)	231.7 (200.5, 265.1)
Age 15–24	20.8 (17.7, 24.2)	11.2 (9.5, 13.1)	21.7 (18.4, 25.4)	92.6 (82.0, 103.9)	50.8 (44.8, 57.1)	98.8 (87.1, 111.4)	887.2 (773.7, 1008.5)	480.0 (419.2, 545.1)	911.7 (796.8, 1034.5)
Age 25–64	9.0 (8.0, 10.3)	5.2 (4.6, 5.9)	9.7 (8.6, 11.0)	45.3 (40.8, 50.0)	26.3 (23.6, 29.2)	48.7 (43.5, 54.3)	341.7 (314.4, 370.1)	186.0 (171.1, 201.5)	333.4 (306.8, 361.2)
Age 65+	15.3 (12.9, 18.6)	8.1 (6.8, 9.7)	18.1 (15.3, 21.5)	67.0 (60.5, 74.5)	35.4 (32.1, 39.0)	78.1 (70.7, 86.1)	231.1 (210.3, 253.1)	122.4 (111.5, 133.8)	264.9 (241.0, 289.8)

Note: Rates by mode adjusted for sex and age; rates by sex adjusted for mode and age; rates by age adjusted for mode and sex. Emergency department rates for 2004–2009 only.

Table 5
Average annual adjusted traffic injury rates, standardized by race/ethnicity, sex, and travel mode, Wisconsin, 2001–2009.

Person characteristics, travel mode ^a	Fatal injury rate and 95% CI			Inpatient injury rate and 95% CI		
	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles
Motor vehicle	9.4 (8.0, 10.9)	5.1 (4.4, 5.9)	8.5 (7.3, 9.9)	43.6 (39.4, 48.0)	23.3 (21.1, 25.7)	38.3 (34.6, 42.1)
Motorcycle	662.7 (576.0, 764.7)	322.3 (243.0, 481.5)	890.7 (402.4, 2143.2)	3924.7 (3306.2, 4602.3)	2357.5 (1785.6, 3043.6)	9720.6 (6162.1, 14,227.8)
Walk	12.0 (8.5, 16.4)	6.8 (4.6, 9.6)	98.9 (67.6, 140.4)	62.1 (50.5, 75.4)	35.4 (28.5, 43.5)	489.8 (396.6, 597.6)
Bicycle	24.9 (10.2, 51.3)	7.2 (3.5, 14.0)	122.0 (52.3, 243.6)	187.4 (124.5, 271.9)	53.8 (36.3, 77.8)	1046.0 (743.4, 1430.4)
Male	14.3 (12.3, 16.7)	7.7 (6.4, 9.5)	16.3 (12.0, 24.8)	62.2 (55.0, 70.0)	35.5 (30.2, 41.5)	96.5 (73.3, 124.9)
Female	6.8 (5.3, 8.7)	4.0 (3.1, 5.0)	8.1 (6.2, 10.6)	40.6 (35.4, 46.4)	23.6 (20.5, 27.0)	46.4 (40.2, 53.5)
American Indian	40.1 (29.3, 53.3)	21.3 (15.0, 29.2)	62.1 (39.6, 91.3)	106.3 (82.1, 137.2)	54.4 (41.3, 70.9)	145.7 (103.9, 198.9)
Asian	9.0 (4.9, 15.0)	9.1 (2.7, 23.8)	54.4 (7.2, 177.1)	39.8 (28.9, 53.0)	87.5 (51.9, 133.2)	723.6 (408.9, 1128.9)
Black	12.7 (9.1, 17.5)	5.1 (3.6, 6.9)	12.1 (8.2, 17.3)	94.2 (80.5, 110.0)	38.0 (32.7, 44.0)	93.2 (78.6, 109.8)
Hispanic	10.7 (7.8, 14.2)	5.8 (4.2, 7.8)	12.9 (9.5, 16.9)	40.4 (33.2, 48.5)	22.2 (18.2, 26.8)	47.6 (39.6, 56.2)
White	9.9 (8.7, 11.2)	5.7 (5.1, 6.5)	10.6 (9.3, 11.9)	46.3 (41.7, 51.2)	27.1 (24.4, 30.1)	49.4 (44.4, 54.8)

Note:

^a Rates by mode adjusted for sex and race/ethnicity; rates by sex adjusted for mode and race/ethnicity; rates by race/ethnicity adjusted for mode and sex.

Pedestrians' fatal and inpatient injury risk is only slightly higher than the risk to motor vehicle occupants when measured by person-trips and person-minutes, yet is more than ten times higher when measured per person-mile. Pedestrians have lower rates of emergency department injury compared to motor vehicle occupants per person-trip and person-minute, but the rates for pedestrians are higher than those for motor vehicle occupants per person-mile. Relative to motor vehicle occupants, bicyclists face higher travel risk than pedestrians. The ratio of bicyclist to motor vehicle occupant fatalities per person trip is 2:1. These differences are significant at $\alpha = 0.05$. When adjusted for race and ethnicity, the differences between modes remains; the risk of bicycle and pedestrian travel is slightly higher, whereas the risk of motorcycle travel is somewhat lower.

For fatal and inpatient injuries, and across all three measures of exposure, men's travel risk is higher than women's, but women are more likely to experience injuries treated in emergency departments. These differences are significant at $\alpha = 0.05$.

The pattern by age group is what one would expect. Children are relatively protected, and adolescents and older travelers face higher risk of fatal and inpatient injuries compared to adults age 25–64. Older travelers face lower risk of emergency department injury compared to adults age 25–64. These differences are significant at $\alpha = 0.05$.

American Indians face higher fatality and inpatient injury risk across all three measure of exposure. The fatality rate ratio of American Indians to Whites per person trip was more than 4:1, and the inpatient injury rate ratio per person-trip was more than 2:1. The fatality rate ratio of Black to White travelers per person-trip was 1.3. These differences are significant at $\alpha = 0.05$. Other standardized fatality rate ratios by race were not significant at $\alpha = 0.05$. Most inpatient injury rate ratios were significant, and these ratios indicate that American Indians and Blacks face higher travel risk across all three measures, and Asian travelers had the highest relative inpatient injury risk per person-minute and person-mile of travel. Across most measures, Hispanic travelers did not have rates significantly different from White travelers, except for where Hispanic travelers have lower risk of inpatient injury per person-minute of travel.

4. Discussion

When we represent the burden of traffic-related injuries with basic counts, the problem seems to affect mainly adult, White, male motorists. Rates with population-based measures of

exposure highlight the burden to adolescents, American Indians, and Blacks. The advantage of using rates calculated with travel-based measures of exposure is that they allow comparison of the risk of travel by mode. Joining multiple metrics together into one analysis reveals some of the patterns that make road safety and traffic injury prevention a complicated and difficult public problem.

One pattern is that most travel in Wisconsin already occurs by the relatively safest mode, the private automobile (with the possible exception of adolescent travelers who, at the national level, are safest when they are *not* motor vehicle occupants (Beck et al., 2007)). A strategy for reducing traffic injuries would be to reduce the risk of travel for those who have relatively higher risk such as motorcyclists, adolescents, and bicyclists, while continuing to protect motor vehicle occupants. This is important to differentiate transportation injury risk across different travel modes as transportation and public health policies and programs promote increasing walking and bicycling.

The second pattern is that the road transportation system is not equally safe for all demographic groups. The focused effort to protect children has been successful, but adolescents, older drivers, American Indians, and Blacks in Wisconsin all face increased risks each time they travel. The root causes of these patterns are likely different for each group. One approach to reducing these disparities would be to focus analysis and prevention on the travel patterns, behaviors, and environments of specific demographic groups, rather than the population as a whole, or all motorists.

4.1. Motorcyclists

By all of the travel-based measures of traffic-related injury risk considered in this study, motorcyclists in Wisconsin experience the greatest travel risk, and the number of injuries is not small. Motorcyclists account for 13% and 16% of the annual traffic-related fatalities and inpatient injuries, respectively, in Wisconsin, but a small fraction of the travel. The 2009 Wisconsin Add-On to the NHTS illustrates the potential variability in estimates of motorcycle travel, but even if motorcycle trips doubled, the fatality rate ratio of motorcycle travel compared to motor vehicle travel would be in the range of 35:1–45:1. The NHTSA reported that in 2011 at the national level, motorcyclists were about 30 times more likely to die in a motor vehicle crash than a motor vehicle occupant (NHTSA, 2013). Thus, the relative risk of motorcycling in Wisconsin is similar to or higher than the national average.

Recreational motorcycling is popular in Wisconsin, and Harley-Davidson was founded in the state and has its headquarters there.

Table 6
Adjusted traffic injury rate ratios per person-trip, person-minutes, and person-miles, standardized for age, sex, and travel mode, Wisconsin, 2001–2009.

Person characteristic, mode	Fatal injury rate ratio and 95% CI			Inpatient injury rate ratio and 95% CI			Emergency department injury rate ratio and 95% CI		
	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles	Per 100 million person-trips	Per billion person-minutes	Per billion person-miles
	Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent
Motor vehicle	91.0 (81.6, 101.3)	77.9 (68.2, 88.5)	89.8 (75.4, 105.8)	114.1 (101.4, 127.8)	95.2 (84.6, 106.5)	102.5 (91.1, 114.8)	29.4 (27.5, 31.5)	24.6 (23.0, 26.3)	27.2 (25.5, 29.1)
Motorcycle	1.2 (1.1, 1.3)	1.1 (1.0, 1.2)	1.1 (1.0, 1.2)	1.3 (1.2, 1.4)	1.2 (1.2, 1.4)	1.1 (1.1, 1.2)	0.5 (0.5, 0.5)	0.5 (0.4, 0.5)	4.2 (4.1, 4.6)
Walk	2.0 (1.5, 2.6)	1.4 (1.1, 1.8)	10.5 (7.9, 13.5)	3.1 (2.7, 3.5)	2.3 (2.1, 2.7)	17.1 (14.9, 19.4)	1.7 (1.7, 2.0)	1.5 (1.4, 1.6)	10.2 (9.5, 10.9)
Bicycle	2.1 (1.9, 2.3)	2.0 (1.8, 2.2)	1.9 (1.8, 2.1)	1.5 (1.4, 1.6)	1.4 (1.3, 1.5)	1.4 (1.3, 1.5)	0.9 (0.8, 1.0)	0.8 (0.8, 0.9)	0.8 (0.7, 0.8)
Male	Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent
Female	0.2 (0.2, 0.3)	0.3 (0.2, 0.3)	0.3 (0.2, 0.4)	0.3 (0.2, 0.3)	0.3 (0.2, 0.3)	0.4 (0.3, 0.5)	0.3 (0.2, 0.3)	0.3 (0.3, 0.3)	0.3 (0.3, 0.4)
Age 0–4	0.4 (0.2, 0.3)	0.4 (0.3, 0.6)	0.7 (0.4, 1.0)	0.4 (0.4, 0.4)	0.4 (0.4, 0.5)	0.6 (0.5, 0.7)	0.5 (0.4, 0.5)	0.5 (0.5, 0.6)	0.7 (0.6, 0.8)
Age 5–14	2.3 (2.0, 2.6)	2.1 (1.9, 2.4)	2.2 (2.0, 2.5)	2.0 (1.9, 2.2)	1.9 (1.8, 2.1)	2.0 (1.9, 2.2)	2.6 (2.3, 2.9)	2.6 (2.3, 2.9)	2.7 (2.5, 3.0)
Age 15–24	Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent	Referent
Age 25–64	1.7 (1.5, 1.9)	1.6 (1.4, 1.7)	1.9 (1.7, 2.0)	1.5 (1.4, 1.6)	1.3 (1.3, 1.4)	1.6 (1.5, 1.7)	0.7 (0.6, 0.7)	0.7 (0.6, 0.7)	0.8 (0.7, 0.9)
Age 65+									

The state has a partial helmet law that requires only minors and individuals with an instructional permit to wear helmets. Regardless of whether motorcycle travel is utilitarian or recreational, reducing the risk of motorcycle travel is in the public interest. This study did not focus on the causes of motorcycle travel risk, but it warrants further investigation (Lin and Kraus, 2009; NHTSA, 2007).

4.2. Bicyclists and pedestrians

The travel-based measures of exposure highlight the risk of physically active travel, which is increasingly encouraged by transportation and public health officials and advocates. When measured per person-trip, pedestrians face somewhat higher fatal and inpatient risk than motor vehicle occupants, and slightly lower emergency department treated injury risk. However, when measured per person-mile of travel, the fatality risk to pedestrians is about 11 times higher than that experienced by motor vehicle occupants (adjusting for demographic factors). Bicyclists face about twice the fatality and hospitalized injury risk per-person trip compared to motor vehicle occupants (adjusting for demographic factors), and more than 10 times the risk when measured per person-mile of travel.

The trip-based measure of exposure normalizes the difference in speed across the modes, whereas the distance-based measure highlights that walking and bicycling are slow modes and on average cover a shorter distance per trip. This analysis demonstrates that a portfolio of indicators helps to tell a more complete story than one told with only a single indicator. However, it is challenging to measure precisely the relative risk of walking and bicycling because large travel surveys may under-represent these trips. The variability in the estimate of walk trips between the 2001 and 2009 Wisconsin Add-On to the NHTS exemplifies this point, and we need additional research and data collection to understand the relative risk of these modes for different populations.

4.3. Racial and ethnic groups

Compared to other racial and ethnic groups, American Indians in Wisconsin face the highest fatality and inpatient injury risk from travel, controlling for sex and mode of travel. Black and Asian travelers also have higher inpatient injury risk compared to other racial and ethnic groups. This analysis shows that each time a member of these racial and ethnic groups in Wisconsin travels, they face higher risk, and that despite the small numbers overall, these groups experience a disproportionate burden of travel risk.

We do not posit that race and ethnicity have a causal relationship with transportation injury. Instead, race and ethnicity are likely proxies for low SES, which could influence transportation injury through access to protective travel environments or vehicles, for example. It is likely that a portion of this risk can be explained by low SES as in Braver (2003), but we did not have SES data to test this hypothesis in this study. In 2000, Wisconsin's poverty rate for Blacks was 32%, American Indians 22%, Asians (the largest group was Hmong) 20%, and Hispanics 22% whereas the overall poverty rate in the state was only 8.7%. Forty-two percent of Black children, 27% of American Indian children, 23% of Asian children, and 25% of Hispanic children in Wisconsin lived in poverty in 2000 (Wisconsin Department of Health and Family Services, 2008).

4.4. Utility of using multiple measures of exposure

Demographic groups in Wisconsin do not exhibit a great deal of variation in trip duration or distance, and using different measures of travel exposure did not lead to materially different conclusions about traffic injury risk, except for the case of pedestrians and bicyclists. This suggests that using multiple measures of exposure,

Table 7

Adjusted traffic injury rate ratios per person-trip, person-minutes, and person-miles, standardized for race/ethnicity, sex, and travel mode, Wisconsin, 2001–2009.

Person characteristic, mode	Fatal injury rate ratio and 95% CI			Inpatient injury rate ratio and 95% CI		
	Person-trip	Person-minute	Person-mile	Person-trip	Person-minute	Person-mile
Motor vehicle	Referent	Referent	Referent	Referent	Referent	Referent
Motorcycle	70.7 (62.6, 79.7)	63.1 (46.0, 83.2)	104.4 (28.6, 229.2)	90.0 (78.9, 102.1)	101.0 (83.5, 120.5)	254.1 (167.4, 359.3)
Walk	1.3 (1.1, 1.5)	1.3 (1.1, 1.6)	11.6 (10.0, 13.4)	1.4 (1.3, 1.6)	1.5 (1.4, 1.7)	12.8 (11.7, 13.9)
Bicycle	2.7 (1.3, 4.5)	1.4 (0.8, 2.2)	14.3 (8.0, 22.4)	4.3 (3.3, 5.4)	2.3 (1.8, 2.8)	27.3 (22.4, 32.8)
Male	2.1 (1.9, 2.4)	1.9 (1.7, 2.2)	2.0 (1.5, 2.7)	1.5 (1.4, 1.7)	1.5 (1.4, 1.6)	2.1 (1.7, 2.5)
Female	Referent	Referent	Referent	Referent	Referent	Referent
American Indian	4.1 (3.4, 4.8)	3.7 (3.1, 4.4)	5.9 (4.6, 7.3)	2.3 (2.0, 2.6)	2.0 (1.7, 2.3)	2.9 (2.4, 3.5)
Asian	0.9 (0.7, 1.2)	1.5 (0.5, 3.4)	5.5 (0.4, 15.5)	0.9 (0.7, 1.0)	3.2 (2.1, 4.7)	14.6 (8.5, 22.5)
Black	1.3 (1.1, 1.5)	0.9 (0.7, 1.0)	1.1 (1.0, 1.4)	2.0 (1.9, 2.2)	1.4 (1.3, 1.5)	1.9 (1.7, 2.1)
Hispanic	1.1 (0.9, 1.3)	1.0 (0.8, 1.2)	1.2 (1.0, 1.5)	0.9 (0.8, 1.0)	0.8 (0.7, 0.9)	1.0 (0.9, 1.1)
White	Referent	Referent	Referent	Referent	Referent	Referent

including travel-based measures, is a useful method for making comparisons across travel modes, and is important when there are reasons to believe that there are differences in travel patterns and behaviors across demographic groups.

In cases such as this one where there is not much variation in trip duration across demographic groups, using person-trips instead of person-minutes of travel is the better choice of exposure measures because it is more reliable (because of recall) (McGuckin, 2012; Scholssberg et al., 2007). If the data were collected with GPS instead of travel diaries, either measure could be used.

Including the person-miles comparison highlights the vulnerability of the slow modes. It raises the question of whether we should equalize slow and fast modes with our exposure measures, or highlight the differences. Again, using multiple measures and comparing them is the conservative choice, and poses very little extra cost.

4.5. Limitations of this study and future work

Although this study addresses travel mode, age, sex, and race/ethnicity, it unfortunately does not include information about socio-economic status (SES) because SES variables (e.g., education, income, employment status) were not available. Further study of travel risk by SES, travel mode, and other population characteristics is needed. The relative risk of travel of American Indians and Blacks, compared to Whites, may be a function of SES, the travel environment, and road safety policy. The study is also limited by small numbers of injury events, which prohibited standardizing rates for age, sex, and race/ethnicity.

A second limitation of this study is geography; the study is limited to Wisconsin only. The road safety experience of Wisconsin needs to be considered in the geographic, climatic, social, and political context of other states. Expanding the analysis to other states that participate in add-on surveys to the NHTS would be a next step.

Another element of geography missing from this study is that we do not know exactly where people travel, and therefore how local environments influence risk. Additional inquiries should investigate the geographic dimensions of these risk profiles to understand whether differences across modes and demographic groups are more likely to occur in urban or rural areas, or in particular regions of the state.

Furthermore, variability in estimates of pedestrian, bicycle, and motorcycle travel raises questions about the validity of estimates of the travel risk of these modes.

4.6. Policy implications

This study provides information in support of prioritizing motorcycle injury prevention in Wisconsin. Motorcycle injuries

represent a significant minority of deaths and inpatient injuries in the state, and motorcycles are the mode of travel with the highest injury risk. Helmet use is protective (Sauter et al., 2005), and other sources of protection (e.g., training, gear, road design) need to be explored as policy options. This study also supports further investigation and prioritization of bicycle safety in Wisconsin.

The safety statistics that the Wisconsin Department of Transportation reports include total crashes, total fatalities, total injuries, and rates per population and vehicle-miles of travel, but they do not allow for comparison of injury risk across modes. The statewide pedestrian plan discusses safety and reducing the number of pedestrian fatalities, injuries, and crashes, but the metrics do not express the relative risk of walking (Wisconsin Department of Transportation, 2002). The 1998 statewide bicycle plan lamented not having more information about the exposure of bicyclists (Wisconsin Department of Transportation, 1998). Using representative travel data generated by activity surveys is one way to meet this need for additional metrics to guide policy and implementation of countermeasures.

Using additional metrics highlights a common road safety policy dilemma: should we invest to protect high numbers of travelers, or fewer travelers with higher risk? This dilemma is particularly apparent with respect to pedestrians, bicyclists, American Indians, and Blacks. There are many reasons to reduce the relatively high risk of relatively small populations. The first is fairness and justice: racial and ethnic minorities should not bear a disproportionate burden of travel risk. A second rationale is practical: if motor vehicle travel is already relatively safe, achieving additional reductions in motor vehicle travel may require large changes in technology (i.e., vehicles, roads, enforcement) or policy (i.e., speed, enforcement) that may be politically or financially costly, whereas there is greater potential to protect travelers by other modes. A third reason is social and economic: all travel options should be safe options, particularly as transportation and public health policy invests in shifting travelers to active modes of travel.

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