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Linking transportation and population health to reduce racial and ethnic disparities in transportation injury: Implications for practice and policy

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ABSTRACT

In both developing and advanced economies, it is commonly believed that lower income and minority populations are disproportionately at risk of being injured or killed in a motor vehicle crash, especially as pedestrians. However, this risk is rarely quantified with information about exposure. We argue that a combined transportation–population health framework is one way to quantify, and therefore prioritize, equity considerations in transportation safety decision-making. We illustrate this approach with an analysis that compares age-adjusted fatal and nonfatal injury rates per 100 million person-trips by race/ethnicity and sex for motor vehicle occupants, bicyclists, and pedestrians. We found that, per trip, whites are equally safe as pedestrians and motor vehicle occupants, whereas other racial and ethnic groups for whom we have data are less safe when they walk. In addition, black/African-American female motor vehicle occupants and pedestrians have higher inpatient injury risk than female travelers of other races and ethnicities (for whom we had sufficient data). Such differences in transportation injury risk by race and ethnicity warrant deeper analysis to understand the underlying reasons, such as whether certain groups of travelers are exposed to qualitatively different hazards when they travel. We discuss frameworks for including information about injury disparities in decision-making.

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Population health; race and ethnicity; road safety; transportation equity; walking

1. Introduction

The burden of transportation injury is significant. Globally, transportation injuries were the eighth leading cause of death in 2010, killing 1.33 million people and accounting for 2.5% of all deaths (Global Road Safety Facility; The World Bank; Institute for Health Metrics and Evaluation, 2014). Yet, these summary figures do not reveal inequalities in the distribution of transportation injuries across populations.

Inequalities in transportation injuries manifest at multiple scales: in gradients across high- and low-income countries, across rich and materially deprived neighborhoods, and across households and individuals with high and low social status (Laflamme, Burrows, & Hasselberg, 2009a). Socioeconomic factors—often working in combination with race and ethnicity, urbanization patterns, and travel modes—contribute to these disparities in transportation injury (Nantulya & Muli-Musiime, 2001; Nantulya & Reich, 2003). Motivations for eliminating such disparities are grounded in concepts of justice and pragmatism (Laflamme et al., 2009b).

The field of road safety has existing policy tools, such as road safety targets, that can be used to identify and reduce road safety disparities. However, these tools are not currently applied to promote equity because decision-makers often lack fundamental data about the demographic characteristics of travelers, such as socioeconomic status, race, and ethnicity. Robust injury surveillance systems are seen as a fundamental step toward improving road safety in the developing world (Nantulya et al., 2003; Peden et al., 2004). Yet, even well-established road safety surveillance systems remain limited in their application to certain equity concerns.

We argue that linking transportation and population health frameworks is one way to prioritize equity in transportation injury prevention. As a complement to traditional prevention strategies based primarily on road, vehicle, and behavioral risk factors, integrating knowledge and methods from transportation and population health can help understand how policies and countermeasures may have differential effects on road safety outcomes across populations (Kindig & Stoddart, 2003).

To illustrate this approach, we present an analysis that quantifies which types of travelers have higher injury risk—accounting for exposure. Our analysis includes bicyclists, pedestrians, and motor vehicle occupants by race/ethnicity, sex, and age. The vast majority of studies of transportation injury that include information about race and ethnicity do not account for differences in exposure across travel modes. Previous studies that have accounted for exposure did so only for motor vehicle occupants, and these studies did not consider other modes of travel such as walking and bicycling. This study addresses this fundamental gap at the intersection of safety, travel behavior, race, and ethnicity.

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To place road safety disparities in a larger policy context, we also discuss the additional data, analytical, and policy tools needed to develop and implement an evidence-based strategy to eliminate transportation injury disparities.

2. Health disparities and transportation injury prevention

Health disparities can be defined as any observed difference in health status between people or groups, but the concept is usually intended to show the "systematic, plausibly avoidable health differences adversely affecting socially disadvantaged groups" (Braveman et al., 2011, p.S151). The arguments for eliminating health disparities are both economic and moral, and both aspects apply to the case of transportation injury. Estimates of economic losses from transportation injury range from 1% to 2% of gross domestic product (GDP), but they may be as high as 4% in India and 10% in Uganda (Blincoe, Miller, Zaloshnja, & Lawrence, 2015; Global Road Safety Facility; The World Bank; Institute for Health Metrics and Evaluation, 2014; Peden et al., 2004).

Above and beyond economic arguments: If all people are valued equally, and if good health is essential to well-being, then each person should have access to good health regardless of race, ethnicity, socioeconomic status, or other characteristic associated with discrimination (Phase I Report, 2008). Travel is an essential part of well-being and good health because it allows people to carry out everyday activities such as going to work and school. Therefore, each person should be able to travel safely.

2.1 *Racial, ethnic, and socioeconomic differences in transportation injury risk*

The majority of studies of racial and ethnic disparities in road safety in the United States have used population-based measures of exposure that indicate the incidence of transportation injury for a given population (Campos-Outcalt, Bay, Dellapena, & Cota, 2002, 2003; Harper, Marine, Garrett, Lezotte, & Lowenstein, 2000; Schiff & Becker, 1996; Stevens & Dellinger, 2002). Other studies have used an ecological approach to show that certain neighborhoods are associated with poorer safety outcomes for vulnerable groups (Braddock, Lapidus, Gregorio, Kapp, & Banco, 1991; Dougherty, Pless, & Wilkins, 1990; Rivara & Barber, 1995).

However, population- and area-based measures do not allow for comparison of injury risk across travel modes because they do not account for differences in exposure. Travel-based measures of exposure should be used because factors such as race, ethnicity, family composition, and employment status influence travel behavior (Giuliano, 2003; Kerr, Frank, Sallis, & Chapman, 2007; U.S. Federal Highway Administration, 2000). The implication for injury prevention research is that risk metrics that do not account for travel-based exposure misrepresent the true population risk when there is heterogeneity in travel.

Previous studies that used travel-based measures of exposure to analyze injury risk by race and ethnicity have considered only motor vehicle occupants. In the United States, among children aged 5–12 years, motor vehicle occupant fatality rates per billion vehicle-miles of travel were highest for blacks/African-Americans and lowest for whites, with rates for Hispanic/Latino children in between (Baker, Braver, Chen, Pantula, & Massie, 1998). When adjusting for socio-economic status (SES), Braver (2003) found that black/African-American and Hispanic/Latino adult men have higher fatality rates per trip as motor vehicle occupants relative to whites. In addition, SES was a stronger determinant of motor vehicle death rates than race and ethnicity (Braver, 2003).

In this study, we address this important gap by quantifying transportation injury risk by race and ethnicity across multiple travel modes using travel-based measures of exposure.

3. Research strategy, methodology, and data

3.1 *Study area*

The study area is the state of Wisconsin in the United States, which had a population of 5.7 million in 2012 (U.S. Census, 2014). Its economy includes significant agricultural and manufacturing production, and its settlement patterns include large metropolitan areas, low-density suburbs and exurbs, and small cities and towns. Private automobiles are the dominant travel mode in Wisconsin; yet, walking, bicycling, and public transport are important modes for both utilitarian and recreational travel.

3.2 *Data and data quality*

This analysis includes two transportation injury outcomes: fatalities and nonfatal injuries requiring a hospital stay. We use the phrase "inpatient injuries" to refer to those injuries requiring a hospital stay. Fatal and inpatient injury outcomes are mutually exclusive in this analysis. Victims who died within 30 days of a crash are counted as fatalities.

Data for fatalities (2001–2009) are from the Fatality Analysis Reporting System (FARS), which is a national database of police-reported fatal crashes. Race and ethnicity data in FARS come from death certificates. Wisconsin's reporting rate for race and ethnicity to the FARS database is at least 90% (Briggs et al., 2005).

Data for non-fatal injuries are from hospital inpatient discharge records (not including emergency department records). These hospital discharge data include external causes of injuries (E codes) for about 99% of observations, and the inpatient data set included information about the race and ethnicity of victims for 97% of observations (information about race and ethnicity is sometimes self-reported) (Lawrence, Miller, Weiss, & Spicer, 2007).

We used the 2001 Wisconsin Add-On to the National Household Travel Survey (NHTS) to compute trip-based measures of exposure for each travel mode in this analysis. This survey had an unweighted sample of 17,000 households and 160,000 unlinked person-trips. The weighted trips account for population estimates and non-response, but undercoverage by race and Hispanic/Latino ethnicity are only partially corrected by survey weighting (Proussaloglou, Popuri, Aunet, & Cipra, 2004; Santos, McGuckin, Nakamoto, Gray, & Liss, 2011). The

person-trips in our analysis include all access and egress trips to transit (e.g., walk to transit).

We used the 2009 survey (1707 households) to provide information about the sensitivity of the results of the analysis of the 2001 survey. We replicated the analysis using a linear interpolation of 2001 and 2009 data. Comparison measures are not available for all groups because the 2009 travel survey did not include trips for all populations (e.g., female bicyclists over the age of 65 years, black/African-American male bicyclists, and children aged 0–4 years). In addition, the estimates of walk and bicycle trips for 2009 are less reliable than the estimates for 2001 because they are based on smaller numbers of reported trips (several groups have $N \leq 10$).

In this manuscript, we follow the official "Revisions to the Standards for the Classification of Federal Data on Race and Ethnicity" adopted by the Office of Management and Budget in 1997 (U.S. OMB, 1997). These racial and ethnic classifications include: white, black or African-American, American Indian or Alaskan Native, Asian or Pacific Islander, and Hispanic or Latino. Although race and ethnicity are important elements of health surveillance systems, these are social constructs without agreed-upon definitions.

In our analysis, white, black/African-American, American Indian/Alaskan Native, and Asian/Pacific Islander categories do not include individuals who identify as Hispanic or Latino. We did not analyze the multiracial category because it was not clear how each data set coded respondents who identified with multiple races. Information about race and ethnicity was collected at the household level, not for each traveler, and we assume the same race and ethnicity for all members of the household. According to the 2010 US Census, in Wisconsin, 5.1% of husband-wife partners in the same household had different races or Hispanic/Latino origin. The figures for unmarried partners in households were 13# for opposite-sex partners and 11.6% for same-sex partners (Lofquist, Lugaila, O'Connell, & Feliz, 2012). Therefore, between 5% and 13% of sampled households with married or unmarried partnerships could be expected to have household members of different races or ethnicities. We do not know how this limitation of the survey influences travel estimates.

3.3 *Analytical approach*

To represent transportation injury risk, we calculated average annual travel mode, sex, and race/ethnicity-specific injury rates per 100 million person-trips. We also adjusted these specific rates for age.

We used the gamma distribution for the confidence interval estimates because these intervals are more accurate when the number of injury events is small (Fay & Feuer, 1997; Kochanek, Murphy, Anderson, & Scott, 2004). The confidence intervals account for sampling variation in the travel estimates (because these travel estimates come from a survey) following Flanders (1984) and Fay (1999). In the discussion that follows, statistically significant differences are at the $\alpha = 0.05$ level. All computation was carried out in SAS 9.4.

We excluded motorcyclists from the analysis because of incomplete information for several demographic groups who ride motorcycles; we excluded bus occupants because the number of injury events was too small to support reliable rate estimates.

4. Results and discussion

4.1 *Using travel data to estimate exposure*

Heterogeneity in travel patterns is why it is crucial to conduct safety analyses with travel-based information about exposure. The vast majority of trips in Wisconsin were made by motor vehicle, and there were important differences in motor vehicle use by race and ethnicity (Table 1). Black/African-American women made half as many motor vehicle trips as white women in 2001 (577.5 and 1228.6, respectively), and the pattern was similar for black/African-American and white men.

Table 1. Mean weighted annual trips per person by travel mode and demographic characteristics, Wisconsin, 2001.

	Bicyclist		Pedestrian		Motor vehicle occupant	
	Male	Female	Male	Female	Male	Female
Age 0–14	53.7	23.5	99.2	110.5	826.3	940.9
	N = 1492	N = 794	N = 5269	N = 5259	N = 38,875	N = 38,543
Age 15–24	26.5	10.4	117.1	96.1	1037.5	1047.6
	N = 396	N = 122	N = 2931	N = 2848	N = 24,027	N = 26,211
Age 25–64	10.4	8.5	71.5	82.9	1272.7	1385.4
	N = 1044	N = 578	N = 11,014	N = 14,486	N = 144,951	N = 173,201
Age 65+	1.6	0.4	89.7	68.4	1173.1	892.4
	N = 155	N = 72	N = 2874	N = 3631	N = 38,299	N = 39,221
White	20.3	10.7	80.4	90.1	1206.8	1228.6
	N = 2764	N = 1421	N = 17,439	N = 20,099	N = 220,592	N = 246,775
Black/African-American	4.9	0.3	192.0	69.9	601.1	577.5
	N = 73	N = 43	N = 2047	N = 2826	N = 7920	N = 11,046
Hispanic/Latino	57.4	32.6	88.2	137.4	1090.7	1529.9
	N = 164	N = 61	N = 1802	N = 2271	N = 13,495	N = 14,322
Asian/Pacific Islander	21.4	4.0	101.8	90.8	719.6	1059.5
	N = 75	N = 37	N = 979	N = 1120	N = 8969	N = 9225
American Indian/Alaskan Native	25.8	1.8	27.7	79.5	674.5	881.3
	N = 12	N = 13	N = 146	N = 146	N = 1232	N = 1413

Note: Trips are unlinked and include transit access and egress. Weighted trips expand the sampled trips to represent statewide travel in 2001.

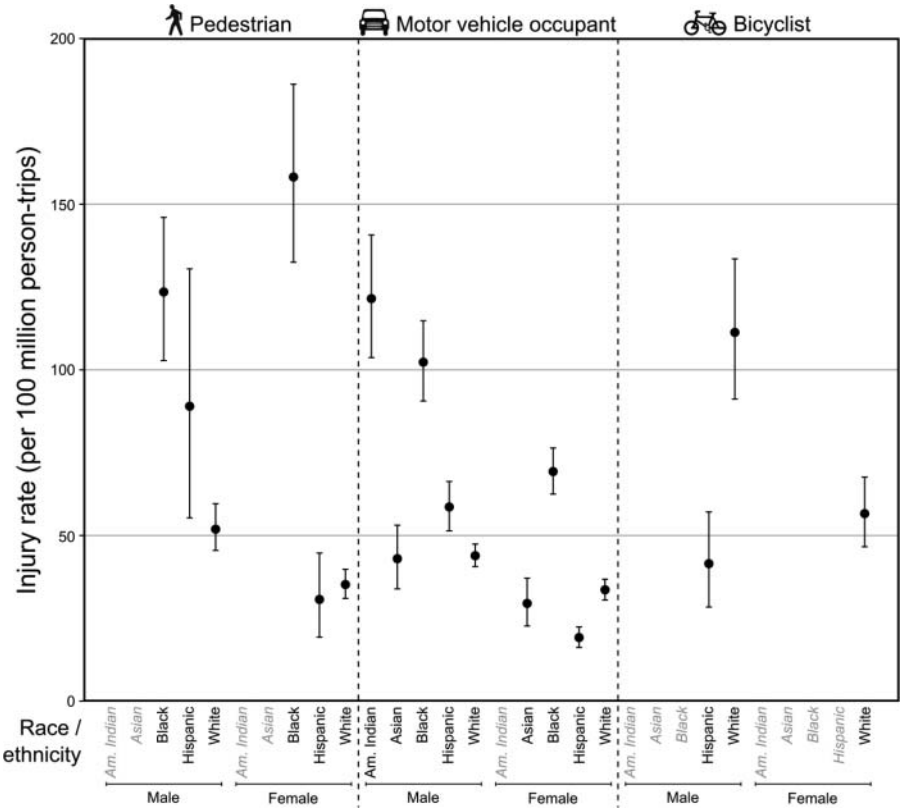

Figure 1. Crude transportation injury (Inpatient) rates and confidence intervals ($\alpha = 0.05$) per 100 million person-trips by race/ethnicity, Wisconsin, 2001–2009. Note: Populations with small numbers of injury events (N < 16) suppressed due to statistical instability of the estimates.

Hispanic/Latino, Asian/Pacific Islander, and American Indian women made 40%, 47%, and 30% more motor vehicle trips, respectively, than men of the same race/ethnicity. White men and women made similar numbers of trips by motor vehicle.

There is also a notable heterogeneity in bicycle and pedestrian travel by sex and race/ethnicity. For instance, black/African-American male pedestrians made more than twice as many trips as black/African-American female pedestrians, whereas Hispanic/Latina female pedestrians made 50% more trips than Hispanic/Latino male pedestrians. Across races and ethnicities, men make more bicycle trips than women.

4.2 *Comparing transportation injury risk by travel mode and race/ethnicity*

Figure 1 presents average annual crude inpatient injury rates per person-trip by travel mode, sex, and race/ethnicity for Wisconsin over 2001–2009. We present inpatient injuries in this figure, rather than deaths, because their higher number compared to fatalities allows for more stable estimates across population subgroups. Table 2 presents the raw counts of fatalities and inpatient injuries for comparison.

Black/African-American female motor vehicle occupants and pedestrians have higher inpatient injury risk than female

Table 2. Fatal and inpatient transportation injuries by travel mode and demographic characteristics, Wisconsin 2001–2009.

	Total fatal and inpatient injuries, 2001–2009 (M = male, F = female)											
	Bicyclist				Pedestrian				Motor vehicle occupant			
	Fatal		Inpatient		Fatal		Inpatient		Fatal		Inpatient	
	M	F	M	F	M	F	M	F	M	F	M	F
All groups	76	16	611	151	281	177	1390	958	3412	1820	13,521	10,513
Age 0–14	19	4	224	62	34	15	339	183	95	74	462	441
Age 15–24	9	1	98	31	47	16	263	130	1109	501	4222	2680
Age 25–64	43	8	255	50	149	81	630	408	1727	835	7103	5113
Age 65+	5	3	34	8	51	65	158	237	481	410	1734	2279
White	67	13	477	131	218	129	879	689	2908	1598	11,169	8957
Black/African-American	5	2	70	10	32	27	330	164	140	59	856	593
Hispanic/Latino	1	1	24	3	16	8	79	36	190	58	644	251
Asian/Pacific Islander	0	0	5	1	6	3	13	12	35	32	139	142
American Indian/Alaskan Native	0	0	5	2	7	6	15	11	81	46	177	167

Table 3. Risk ratios and confidence intervals ($\alpha = 0.05$) comparing the injury risk of walking and bicycling to motor vehicle travel, based on age-adjusted fatal and inpatient injury rates, by sex and race/ethnicity, Wisconsin, 2001–2009.

	Fatalities				Inpatient injuries			
	Bicyclist		Pedestrian		Bicyclist		Pedestrian	
	Male	Female	Male	Female	Male	Female	Male	Female
White	3.0 (2.0, 4.2)	5.5 (1.4, 12.3)	1.2 (1.0, 1.3)	1.1 (1.0, 1.3)	4.7 (3.8, 5.7)	4.6 (3.0, 6.7)	1.2 (1.0, 1.3)	1.0 (0.9, 1.2)
Black/African-American	3.3 (0.8, 7.6)	45.9 (2.0, 161.9)	0.9 (0.6, 1.2)	2.8 (1.7, 4.4)	6.8 (4.5, 9.7)	22.2 (9.6, 40.2)	1.6 (1.3, 1.9)	1.7 (1.3, 2.2)
Hispanic/Latino	0.0 (0.0, 0.1)	15.5 (0.0, 74.1)	0.9 (0.5, 1.5)	1.2 (0.5, 2.3)	7.9 (4.1, 13.1)	6.5 (1.0, 17.7)	1.6 (1.1, 2.2)	1.2 (0.8, 1.9)
Asian/Pacific Islander	0.0	0.0	2.6 (0.9, 5.6)	1.9 (0.4, 5.3)	5.3 (0.2, 19.0)	—	1.3 (0.6, 2.4)	1.5 (0.9, 2.5)
American Indian/Alaskan Native	0.0	0.0	5.5 (2.6, 10.0)	1.0 (0.4, 2.6)	0.6 (0.0, 2.0)	1.3 (0.0, 5.0)	3.5 (1.5, 6.5)	1.0 (0.4, 2.0)

travelers of other races and ethnicities (for whom we had sufficient data). Black/African-American and American Indian male motor vehicle occupants also have higher inpatient injury risk than Asian/Pacific Islander, Hispanic/Latino, and white male motor vehicle occupants. Such differences in transportation injury risk by race and ethnicity warrant deeper analysis to understand the underlying reasons, such as whether certain groups of travelers are exposed to qualitatively different hazards when they travel.

Table 3 presents risk ratios comparing the relative risk of bicycling and walking to motor vehicle travel. These risk ratios use age-adjusted fatal injury and inpatient injury rates to compare the different travel modes.

The analysis of pedestrian travel by racial/ethnic categories, for which we had data, shows that only black/African-American women experience higher risk of fatal injury as pedestrians than as motor vehicle occupants. No other groups show a statistically significant difference between the fatality risk of walking and motor vehicle travel, and this is true for the analysis created with 2001 travel data and the 2001–2009 linear interpolation estimates.

Moreover, the fatality risk associated with pedestrian travel compared to motor vehicle travel for black/African-American women is relatively high. The risk ratio for fatalities is nearly 3:1, and the risk ratio is 1.7:1 for inpatient injuries when measured with 2001 travel data. Black/African-American female pedestrians face nearly three times the risk of dying as pedestrians than they do as motor vehicle occupants and nearly twice the risk of injury requiring inpatient treatment.

Black/African-American and Hispanic/Latino men also face higher injury risk of pedestrian travel compared to motor vehicle travel, whereas white men are equally protected as pedestrians and as motorists.

Travel by bicycle has the highest fatality and injury risk ratios compared to motor vehicle travel. However, rates for bicycle injuries should be interpreted cautiously because of the small number of injury events and because travel information about the race and ethnicity of bicyclists is limited.

5. Translating evidence of road safety disparities into practice

Although professionals and policy makers sometimes have a general awareness of road safety disparities, this awareness does not always influence decision-making. To translate road safety equity research into policy and practice, we need: (1) a better understanding of the underlying mechanisms that cause road safety disparities; and (2) a political model of policy change that enables equity considerations to become more salient.

The historical example of preventing motor vehicle injuries among children highlights how the field of road safety has used research and a population-level perspective to lower child death and injury rates. Through research and practice, the field of road safety recognized that certain road safety interventions were not effective for everyone. Children were central to early road safety movements in the United States, but for many years, child occupants of motor vehicles did not receive special consideration from engineers working to improve the safety of vehicles (Norton, 2008). Thus, "infants were overrepresented among child passenger fatalities despite their relatively low exposure to vehicle travel" (Simons-Morton & Winston, 2006). Over decades, through a combination of translational research, legislation, and technologies designed to protect both children and adults, children have become the safest passengers inside vehicles today.

Contemporary investigations of traffic injuries among children suggest that environmental factors, rather than behavioral factors, best explain why children from lower socioeconomic contexts continue to have higher injury risk than other children (Laflamme & Diderichsen, 2000). This awareness might result in greater emphasis on modifying physical environments and improving road and traffic infrastructures to increase their safety. The same recognition of population-specific hazards and the social and environmental determinants of transportation injury needs to be translated to other populations of travelers and to other transportation modes.

In the following sections, we discuss conceptual frameworks for understanding transportation injury disparities as well as strategies for building a policy agenda for road safety equity.

5.1 *Conceptual frameworks for understanding transportation injury disparities*

A conceptual framework for understanding the causes of transportation injury disparities is a starting point for addressing them through interventions and policy. Figure 2 illustrates this idea with an adaptation of three existing frameworks: (1) the social factors resulting in inequalities in health generally (House, 2002); (2) the social factors resulting in inequalities in injury specifically (Laflamme & Diderichsen, 2000); and (3) the specific phases of a transportation crash event (Haddon, 1972).

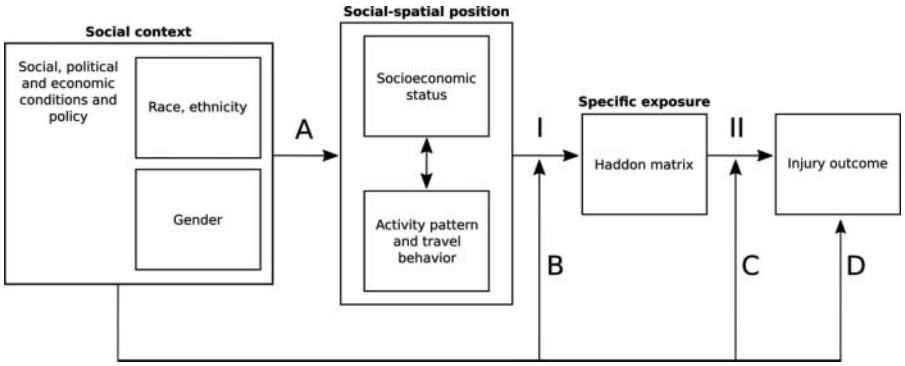

Figure 2. Conceptual framework for understanding social inequalities in transportation injuries. Note: Conceptual framework adapted from Haddon (1972), House (2002), and Laflamme & Diderichsen (2000).

To these three frameworks, we added an emphasis on activity patterns and travel behavior.

Larger social factors such as race, ethnicity, and gender have a direct influence on an individual's socioeconomic status, activity patterns, and travel behavior (pathway A). These larger, social factors also have a direct influence on injury outcomes (pathway D). For example, pathway D includes the neighborhood characteristics or community characteristics—above-and-beyond individual-level factors associated with place—that influence health outcomes (Laflamme & Diderichsen, 2000). Social factors also influence two downstream relationships: differential exposure (pathway I through pathway B) and differential susceptibility (pathway II through pathway C).

To these three existing models, we added the element "activity patterns and travel behavior." Travel is both a social and environmental determinant of health (Ameratunga & Hosking, 2012). We represent individuals' activity patterns and travel behavior in a two-way relationship with their socioeconomic status. Taken together, travel and socioeconomic status represent what we understand to be an individual's social–spatial position. Such factors include the individual-level effects of residential segregation (Williams, Mohammed, Leavell, & Collins, 2010), the accessibility of jobs and other health-promoting activities (Raphael & Stoll, 2010), and activity and travel choice sets, e.g., mode choice, destination choice (Hanson & Hanson, 1981).

This conceptual framework suggests that existing injury prevention strategies may have differential effects depending on a number of social, environmental, and travel behavior factors that influence exposure and susceptibility. It also suggests that entirely new interventions need to be developed to respond to specific pathways. Several of these pathways lie outside the traditional scope of transportation safety practice.

We believe that the relationship between activity patterns, travel behavior, and exposure is a critical concept that needs further development. The travel data for Wisconsin used in our study showed that black/African-American and white female pedestrians tend to walk for different trip purposes. About 80% of black/African-American female pedestrians' trips were for utilitarian travel (e.g., work, school, shopping), and about 20% were discretionary (e.g., recreation, eating out); for white women, the proportions of utilitarian and discretionary travel were 60% and 40%, respectively. Within the category of recreation trips, white women made about 64% of their recreation walk trips for the stated purpose of exercise, which was two times higher than the proportion of walk trips that black/African-American women made in this category. In contrast, black/African-American women made 46% of their recreation walk trips to visit friends, whereas only 16% of white women's recreation walk trips were to visit friends (U.S. Department of Transportation, 2001).

If walking for exercise is associated with safer pedestrian environments, and if utilitarian walking is associated with relatively hazardous pedestrian environments, then reducing disparities between black/African-American and white female pedestrians may depend on how well investment decisions about pedestrian safety account for the land use contexts. Investments in safe walking and bicycling are necessary for both recreational and utilitarian travel environments, and such measures need to be included among best practices (Pollack et al., 2012, 2014).

5.2 *Increasing the salience of transportation injury inequalities in policy*

Although transportation injury disparities are a known problem, they are not always central to transportation safety decision-making processes. Strategies to increase the salience of this public problem can be derived from models of policy change. The public health model of prevention is one example of a model of policy change that is used in transportation safety practice. This model represents a techno-rational approach to policy and decision-making. In this model, including equity concerns in transportation injury occurs as policy moves through developmental phases. This cycle begins with public health surveillance that leads to a descriptive understanding of injury patterns. Then, experts develop a causal understanding of the underlying risk factors of transportation injury disparities. Once risk factors are known, experts and system designers develop and test interventions, and ultimately, decision-makers develop policies to ensure the widespread implementation of the interventions. The cycle begins again with surveillance, indicating whether these interventions resulted in long-run changes in population-level indicators.

Another set of frameworks for policy change emphasizes the political disposition of the problem (Kingdon, 1984; Marsden, Frick, May, & Deakin, 2011; Sabatier, 2010). For example, Kingdon's (1984) framework focused specifically

on national-level transportation policy change. It was inspired by the "garbage can model" of decision-making—one in which organizations simultaneously work with "streams" of problems, solutions, and choices (Cohen, March, & Olsen, 1972) in contrast to the rational model in which there is a clear path between problem definition and solutions. In political models of policy change, issues such as road safety disparities become salient in public policy when: (1) road safety inequalities become a public problem; (2) technical experts have enough information to develop policies to address the problem; and (3) elected officials create political will to address road safety inequalities. Politically oriented models of policy change may work with different underlying philosophies of democracy, and therefore, they differ in the role of experts, advocates, and the lay public (Corburn, 2005; Purcell, 2008). Despite any differences with respect to how they view democracy, models of policy change share the view that science and politics operate together (Jasanoff, 1998), and that knowledge alone—without advocacy—does not result in policy change.

5.3 *Opportunity to use road safety targets to reduce disparities*

We offer two ideas about practical next steps that could advance the inclusion of transportation injury disparities in policy and practice. The field of road safety already uses quantitative targets to "motivate decision making" and to "create a framework" for allocating investment in transportation safety interventions (Allsop, Sze, & Wong, 2011). International research investigating the effectiveness of quantitative road safety targets has found that they are useful, particularly when they are ambitious (Elvik, 1993). We propose that quantitative road safety targets should be used as a strategy to reduce differences in fatality and injury rates across racial and ethnic groups and across travel modes.

For instance, in 2015, the 2030 Agenda for Sustainable Development adopted a road safety target as a new component of its Health Goal: "By 2020, halve the number of global deaths and injuries from road traffic accidents" (U.N. Sustainable Development Goals, 2015; World Health Organization, 2015).

5.4 *Improving transportation and injury data quality*

Although some may argue that taking direct action to improve pedestrian safety is more important than generating analysis, we assert that systemic knowledge of transportation injury risk is also a necessary part of changing practices that widen disparities. Better knowledge of disparities requires both methodological development and data analysis (Deakin, 2007).

It is not possible to conduct an equity-based road safety program without high-quality data for all groups of travelers, even for groups with small populations. We need to prioritize transportation equity and health equity in the design of large-scale, administrative data sources such as the National Household Travel Survey. Oversampling people of color, small populations, and non-automobile travel are strategies that would support a road safety equity agenda, as well as transportation equity and health equity more broadly. Without this information, it is not possible to know whether policies and practices have differential impacts across population subgroups.

6. Limitations

This study was limited to Wisconsin where small numbers of injury events for Asian/Pacific Islander, American Indian, and Hispanic/Latino groups prevented a robust analysis across all demographic groups and travel modes. Using both hospital-reported injury data and police-reported fatalities helped to fill gaps in information, but we still do not know the full extent of potential disparities in travel risk for Wisconsin. Moreover, it was not possible to include information about socioeconomic status in this analysis, which is a likely confounder.

A second limitation of the analysis is that it included information only about fatalities and injuries requiring a hospital stay. We did not include data about injuries recorded as emergency department visits because 45% of these records lacked information about the race and ethnicity of the victim. Racial and ethnic disparities in transportation injuries may have a different pattern when injuries are less severe, and this is a topic for future investigation.

Finally, the specific patterns in injury disparities found in this analysis are likely contingent on local factors that are unique to Wisconsin and its populations. The specific patterns of injury disparities would likely be different in other cities and in other countries. Methodologies and analyses that reveal underlying causes across places are a next step for advancing knowledge of transportation injury disparities.

7. Conclusions

Although transportation safety policy and practice aims to make travel safe for everyone, the field requires data, analytical, and policy tools that enable it to identify whether certain travelers and travel modes are safer than others. This requires using travel-based exposure measures to estimate injury rates, as well as data about social factors that are known to influence transportation injury risk.

In this study, we compared transportation injury risk across travel modes by race/ethnicity and sex using travel-based measures of exposure. The results of the analysis show that certain racial and ethnic groups and genders (for which we had sufficient data) face higher risk as bicyclists and pedestrians than as motor vehicle occupants, including black/African-American women, black/African-American men, and Hispanic/Latino men. Although the majority of transportation injury affects white, male, motor vehicle occupants, it is problematic that certain populations face a higher injury risk each time they travel. This pattern signals that conventional injury prevention strategies do not protect a full range of travelers.

Our results contribute to understanding the problem of inequalities in road safety, and we discuss policy frameworks in which such information could become more salient in decision-making. We suggest that road safety targets are an example of a practice already used by road safety practitioners that could be leveraged to reduce road safety disparities, particularly racial and ethnic disparities. To become more deliberate in

designing transportation and injury prevention systems that protect all travelers, we need to use quantitative evidence about population-level differences in transportation injury risk. This includes using information about differences across racial and ethnic groups to make more informed decisions about improving road safety for all.

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