NorCal Open Access Publications
Journal of Global Epidemiology and Environmental Health
Volume 1; Issue 1
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Research Article

Pedestrian Crossing Behavior in Relation to Grouping and Gender in a Developing Country Context

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Received Date: 30 September, 2017; **Accepted Date:** 23 November, 2017; **Published Date:** 08 December, 2017

Abstract

As planners, policy makers, and engineers in developing countries focus increasingly on motor vehicles, a vital component of the transportation system is being marginalized: the pedestrian. Large percentages of the populationin developing countries are still dependent on walking, yet do not have safe means to do so.With transportation fatalities predicted to become the 4th leading cause of early mortality globally by 2030, this is an important issue, and especially so in the developing world context. The purpose of this paper is to explore pedestrian behavior in terms of safety when interacting with automobiles.The overarching objective is to find which types of pedestrian groups and genders are likely to safely utilize which types of signalization and infrastructure treatments.Once this is understood, we may then plan and design transportation systems that are safer for all users. Data was collected at crossings in Bangalore, India. Independent variables of gender and grouping were compared to the safe usage of available crossing treatments and signalization. Logistic regressions suggest that while solo female pedestrians are the most willing to use available crossing treatments, female pedestrians in groups are the most likely subset to exhibit unsafe crossing behavior.Also, as pedestrian groups become larger, they are less apt to utilize available crossing treatments. Understanding how to best enable safe pedestrian behavior in developing countries will help to inform planning and design decisions that will keep some of the most vulnerable road users safe and combat one of the leading public health barriers.

Keywords

Behavior; Developing Countries; Gender; Grouping; Pedestrian; Safety

Introduction

A paradigm shift in transportation has been occurring over the past few decades in the developing world. A trend towards motorization has proliferated within developing countries, proving to significantly increase personal mobility. However, as motor vehicles have been supported, pedestrians have many times been neglected. This has led to horrific safety outcomes which present a major epidemiological issue.This paper focuses on the interaction between pedestrians and motor vehicles and how that interaction is related to safety. More specifically, which groups of pedestrians resort to unsafe crossing behavior most often, and in which situations does this occur?

Causes of the trend towards motorization are wide ranging and well engrained within the societies in which the change is occurring. They include economic subsidies to both the motor vehicle industry and the purchasers of vehicles, popularization of personal motor vehicles in the media, and few other viable transportation options [1]. India exemplifies this trend towards personal motorization, boasting a 42-fold increase in the total number of registered vehicles in the 34 years from 1981 to 2015, from 5.3 million vehicles to 210.0 million vehicles [2]. Motorized two-wheelers in India are growing at a staggering rate of 12% annually, driving this colossal trend towards motorization [3]. By 2025, it is estimated that there will be at least 620 million personal automobiles (including two- and four-wheeled vehicles) in China and India alone [3].

This desire for motorization is understandable on both a personal and national scale. Motorization rates of countries are highly correlated with economic growth. Developing countries are therefore particularly interested in furthering motorization as a pathway to economic development and competitiveness. Plan-

ners, policy makers, and engineers in developing countries have increasingly focused on building places amenable to motorized vehicles. This focus on efficiently moving large volumes of motorized vehicles has had a staggering influence on transportation systems, land use configurations, and the built environment in general. As national leaders in India have increasingly pursued motorization during the last 60 years, the total mileage of the Indian roadway system has increased 11-fold [4]. The density of roadways within India is now nearly identical to that of the United States [4]. India, and the developing world in general, are quickly becoming places where the movement of vehicles is highly prioritized.

Inevitably, there are winners and losers in this paradigm shift towards motorization. For a variety of social, health, and economic reasons, large percentages of the population in developing countries do not have the option of using motorized vehicles. Many of these people either choose or are forced to spend their time in the transportation system as pedestrians. Specifically, the urban poor are the most likely to be reliant upon non-motorized travel because travel mode choices are limited for low-income individuals across the developing world [5]. In addition, women typically have access to fewer resources, which may reduce their choices for travel. In their mode choice survey of Srinivasapuram, India, Srinivasan and Rogers found that 40% of men's trips were non-motorized, while the majority (73% - 88%) of women's trips were non-motorized [6]. By making more trips by non-motorized modes of travel on congested roadways, these women were put at a greater exposure to risk. Accounting for such pedestrians is vital for the creation of resilient, sustainable, and safe transportation systems [7].

With the high level of risk that pedestrians are exposed to as they try to navigate systems built for efficiently moving motorized vehicles, it comes as no surprise that pedestrians account for approximately 22% of the deaths on the world's roadways [8]. Close to 90% of these deaths take place in low- or middle-income countries [8]. In India, 3.5 million hospitalizations and 200,000 deaths from traffic collisions are predicted in the year 2015, with pedestrians being the largest group affected [1]. In the developing world, pedestrians constitute the highest proportion of road traffic fatalities, with the urban poor making up the majority of victims in these road crashes [5,9]. The transportation situation in the developing world has been appropriately described as being in a state of serious crisis by Pucher et al., [7].

As motor vehicles are further prioritized and pedestrians are further marginalized in the developing world, we can expect to see the aforementioned safety issues become amplified. The only way to truly solve this issue is to have a detailed understanding of how pedestrians and motor vehicles interact with one another. The purpose of this work is to explore in which situations-different genders and groupings of pedestrians resort to unsafe crossing behavior, with unsafe crossing behavior being defined as crossing a roadway without regard to a pedestrian treatment or signal, such as failing to use a pedestrian bridge or marked crosswalk. Because there are such enormous safety inequalities for pedestrians, it is vital to understand how pedestrian behavior differs so that adequate safety treatments and signalization can be planned, designed, and implemented.

Motorization rates throughout the developing world are rapidly increasing. As they do, pedestrians are becoming increasingly marginalized, resulting in poor safety and epidemiological outcomes. This paper will explore how pedestrians interact with motor vehicles, focusing specifically on pedestrians' unsafe crossing behavior and implications for public health outcomes. Usage of available crossing treatments and signals in relation to pedestrian gender and grouping will be examined in order to identify pedestrian crossing treatment best practices.

Literature Review

Understanding pedestrian behavior when interacting with motor vehicles in a developing world context is a significant issue with considerable implications. Certain groups of pedestrians are particularly vulnerable as they utilize their transportation systems, and may be more or less apt to resort to unsafe crossing behavior. For example, the elderly are estimated to account for more than 50% of pedestrian traffic fatalities in OECD countries as they are more likely to have walking impairments and walk more slowly, leading them to adopt smaller safety margins [10-13]. If we can identify particular groups that are apt to exhibit unsafe behavior, and thereby put themselves at heightened risk, we can then work towards improving their situation.

The first pedestrian characteristic that this paper examines is that of grouping. Past research has shown that larger groups of pedestrians move slower than smaller groups due to the need to maintain spatial cohesion [14]. Slower speeds can result in more hesitation when it comes to crossing a street. Groups of pedestrians have also been observed to behave more conservatively than their solo counterparts. For example, it has been shown that pedestrians cross against red lights more often with smaller groups than with larger groups [15]. Also, the size of a pedestrian group has been shown to be positively correlated with the amount of time spent waiting to cross a roadway [16]. However, Shi et al., found that groups will use smaller gaps to cross than solo pedestrians [17]. Faria et al., established that a person is between 1.5 and 2.5 times more likely to cross if their neighbor has started crossing, further suggesting that groups may pursue more unsafe crossing behavior [18]. On the other hand, Gorrini et al., found no significant difference in the accepted safety gap of single pedestrians and pedestrians in groups of two [19]. This body of past research leaves some ambiguity as to whether groups are more likely or less likely to exhibit unsafe crossing behavior. In addition, the bulk of this past research was performed in the developed world rather than the developing world. Examining situations in a developing country will shed light on an important neglected issue.

Along with grouping, the gender of pedestrians can result in

significant differences in crossing behavior. Males have been shown to be at higher risk for both motor vehicle and pedestrian related injuries and deaths [9,20]. Many studies conducted in the developing world have identified males as being more likely to engage in risky behaviors that result in death and serious injuries [21,22]. Specifically, past research has shown that male pedestrians are more likely to exhibit risky behavior when crossing a roadway in the presence of automobiles [23,24]. Zhou and Horrey, when focusing on adolescent pedestrians in China, found that there were significant differences between genders in terms of perceived behavioral control and perceived risk, but no differences in terms of behavioral intentions [25]. However, these studies in China were performed with data from a survey as opposed to observations of actual behavior.

Crossing behavior is also dependent upon signalization and the type of crosswalk markings present [26]. When pedestrians in Ireland were provided with timers that displayed when a pedestrian signal would change, compliance rates rose [27]. Also, the presence of a pedestrian refuge island has been observed to decrease pedestrian compliance [16]. The location at which the pedestrian crosses is highly dependent upon the location of both the crosswalk and the origin and destination points of the trip [28].

Methods

Data was collected by in-person observation at four midblock crossings in Bangalore, Karnataka, India. Consistency in the data was ensured through the utilization of only one single observer, which avoided bias in the results. Independent variables included pedestrian gender and grouping. According to past research, these variables are likely to influence the crossing behavior of pedestrians. Unsafe crossing behavior, defined as not utilizing available pedestrian treatments in the presence of a motor vehicle (such as failing to use a marked crossing or pedestrian bridge), was the binary dependent variable.

In order to study pedestrian behavior in developing countries, site selection in the developing world was necessary. After consideration of a number of different sites, four midblock crossings were selected in the city of Bangalore, Karnataka, India (Figure 1). Bangalore is the fifth largest city in India with a population of 6.5 million in the metro region [29]. The crossings that were studied are located near the center of the city, which was originally built around the year 1537. The pedestrian mode share in Bangalore is approximately 26%, while motorized vehicles make up about 69% of mode share [3]. These relatively high rates of both modes, coupled with the fact that there are high numbers of interactions between the modes, leads to an environment ripe with the possibility of unsafe pedestrian crossing behavior. The sites were selected specifically because of their high volumes of both pedestrians and vehicles.

Figure 1: Mid-block crossing sites.Clockwise from top-left: (1) Marked (with pedestrians not using marked location); (2) Signalized; (3)Pedestrian Bridge; (4) Unmarked.

All of the selected midblock crossings were located on a 5,200 foot (1.58 kilometer) stretch of Hosur Road in Bangalore (Figure 2). Because of this, all of the crossings had similar vehicle counts and compositions (approximately 1,950 vehicles per hour per lane). Other factors, such as speed and road geometry, were controlled for by selecting crossing locations on the same corridor.The midblock crossings included a marked crossing with no signs or signals, a signalized crossing with both signs and markings, a pedestrian bridge crossing, and an unmarked crossing.Counts for the marked and unmarked crossings were taken between 11:45 AM and 2:45 PM on July 22 (Tuesday) and July 31 (Thursday). Counts for the signalized crossing and pedestrian bridge were taken between 11:45 AM and 2:45 PM on July 24 (Thursday) and July 28 (Monday). All counts occurred in 2014 and were taken on days without rain. Each midblock crossing was observed twice for 30 minutes each, for a total of 4 hours of observations. Counts were taken manually. With each crossing, a number of factors were noted: the gender of the pedestrians, the grouping of the pedestrians, and the utilization of the crossing (whether the signalization or markings were adhered to). If a waiting group fragmented (some individuals remained waiting while others crossed), they were not considered as a group. Pedestrians were not counted if they had accompanying items such as strollers or bicycles, as this may have altered crossing behavior. Only children old enough to cross independently were counted in the study.

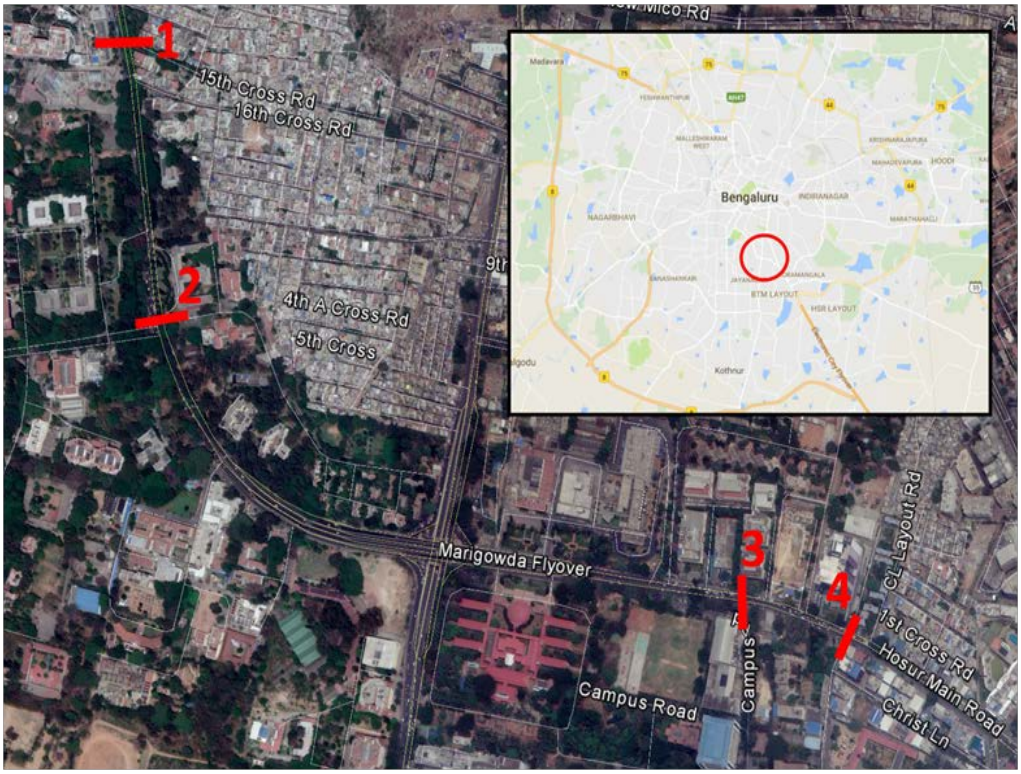

Figure 2: Location of mid-block crossings.(1) Marked; (2) Signalized; (3) Pedestrian Bridge; (4) Unmarked.

Data was only collected when there were moving vehicles present within the roadway. Because a pedestrian did not have the opportunity to exhibit unsafe crossing behavior if there were no vehicles present, data collection was halted if there was a lull in traffic. This scenario occurred very infrequently. In order to proceed with data collection, vehicles had to be close enough to cause a conflict. Conflicts between vehicles and pedestrians were based on the Swedish Traffic Conflict Technique, in which a conflict is defined as: "an observational situation in which two or more road users approach each other in space and time to such an extent that a collision is imminent if their movements remain unchanged" [30]. A group of pedestrians was defined as multiple pedestrians that cohesively sought to cross the roadway using the same path. This could include pedestrians that arrived at the crossing at different times, as long as they were aiming to cross at the same time and to the same point. If multiple pedestrians were waiting together at the side of the road, but they were crossing in different directions or aiming at different points, then they were not considered as a group.

The data was analyzed using SPSS analytical software. Logistic regressions were employed for the analysis. The relationship between grouping and crossing behavior was first analyzed, then the relationship between gender and crossing behavior, and finally the relationship between grouping and gender combined and crossing behavior.

Results

In total, there were 2,137 pedestrians counted. Males made up 57.4% and females 42.6% of the sample. Pedestrians crossed in groups 55.5% of the time, while 45.5% of total crossers were solo.

Grouping and gender

The size of the groups follows an exponential decay at all of the crossings, with approximately 70% of groups consisting of two pedestrians (Figure 3). Data from the signalized crossing are not utilized in the grouping analysis because it was not possible to tell which pedestrians were grouped due to the high volumes of pedestrians and the frequency of crossings.

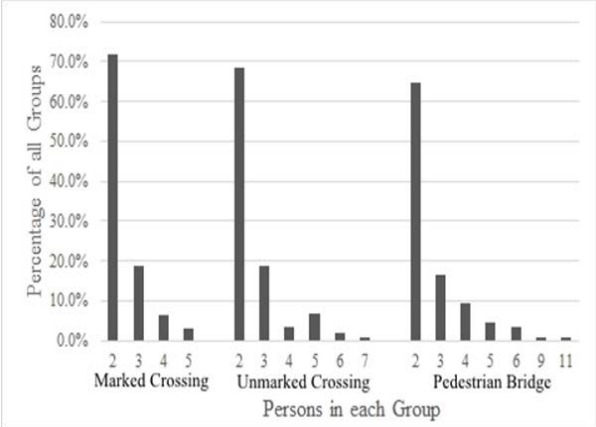

Figure 3: Size of groups at different midblock crossing locations.

Next, the tendency of different genders to cross in groups was explored. While males crossed in groups 45.0% of the time, females were found to cross in groups 72.3% of the time. This tendency for females to cross in groups more often than males was found to be statistically significant through a logistic regression analysis (Table 1).

	B	Odds Ratio	Sig.
Gender vs. Grouping	1.160	3.191	0.000
Note: Independent variable is gender (0 = male, 1 = female).			
Dependent variable is grouping (0 = solo, 1 = grouped).			
	B	**Odds Ratio**	**Sig.**
Grouping vs. Risk	0.276	1.318	0.228
Note: Independent variable is grouping (0 = solo, 1 = grouped).			
Dependent variable is risk (0 = not exhibiting risk, 1 = exhibiting risk).			

	B	Odds Ratio	Sig.
Gender vs. Risk	0.334	1.401	0.061
Note: Independent variable is gender (0 = male, 1 = female).			
Dependent variable is risk (0 = not exhibiting risk, 1 = exhibiting risk).			

Table 1: Logistic regression results.

Note: B = value used in the logistic regression to predict the dependent variable from the independent variable (in log-odds units).

Unsafe crossing behavior - Grouping

Grouping was the first variable that was analyzed in relation to the dependent variable of crossing behavior.It was found that groups are overall more likely to exhibit unsafe crossing behavior, although the relationship was dependent upon location, and was not particularly strong (Figure 4). Logistic regression results suggest that the difference between solo pedestrians' usage of available crossing treatments and grouped pedestrians' usage of crossing treatments is not statistically significant (Table 1).

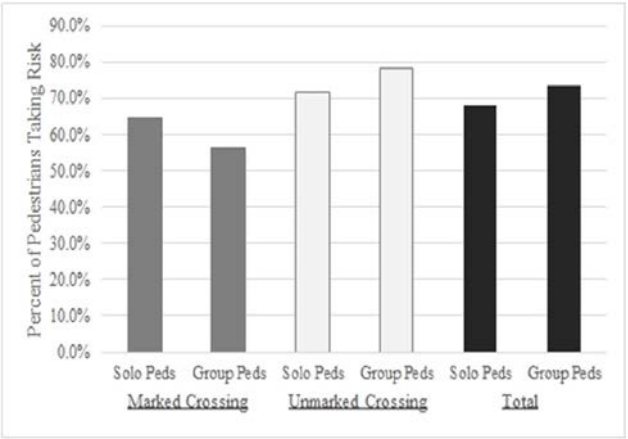

Figure 4: Tendency of groups versus solo pedestrians to exhibit unsafe crossing behavior.

It was found that larger groups are more apt to exhibit unsafe crossing behavior, and solo pedestrians are less likely than any group size to exhibit unsafe crossing behavior (Figure 5). A logistic regression was run to further examine the relationship between group size and unsafe crossing behavior (Table 2). The positive direction of the relationship shows that larger groups are more likely to exhibit unsafe behavior when crossing. The relationship was found to be statistically significant.

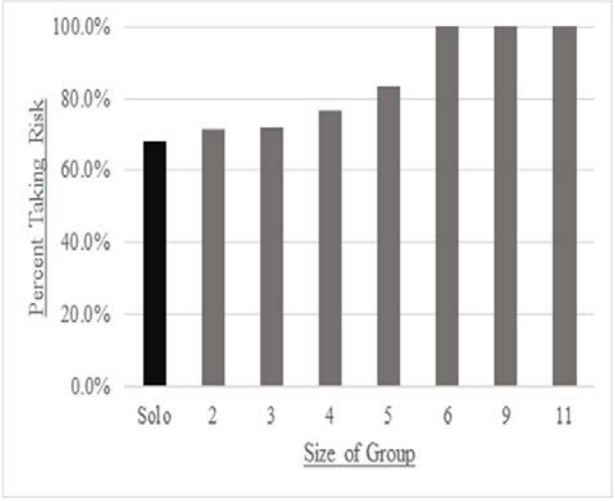

Figure 5: Tendency of group sizes to exhibit unsafe behavior.

	B	Odds Ratio	Sig.
Group Size vs. Unsafe Behavior	0.371	1.449	0.000

Table 2: Logistic regression showing the relationship between larger pedestrian group size and more propensity towards unsafe behavior.

Note: Independent variable is the size of the group that the pedestrian was in.Dependent variable is whether the pedestrian utilized the crossing treatment (0=used the treatment / 1=did not use the treatment).

Unsafe crossing behavior - Gender

Gender was next analyzed in relation to crossing behavior. Overall, females were more likely to disregard crossing treatments, although the relationship was only significant at 90% confidence (Table 1). This goes against findings of past research, and is detailed below in the Discussion section. Groups of different genders were then examined. These groups included groups that were exclusively female, groups that were exclusively male, and groups that consisted of both genders. The average all-male group had 2.41 pedestrians, the average all-female group had 2.73 pedestrians, and the average mixed gender group had 2.98 pedestrians. It was found that the groups consisting exclusively of females were the most likely to disregard available crossing treatments and signalization and exhibit risky crossing behavior. Groups that were composed of both genders were the least likely to exhibit risky crossing behavior (Figure 6).

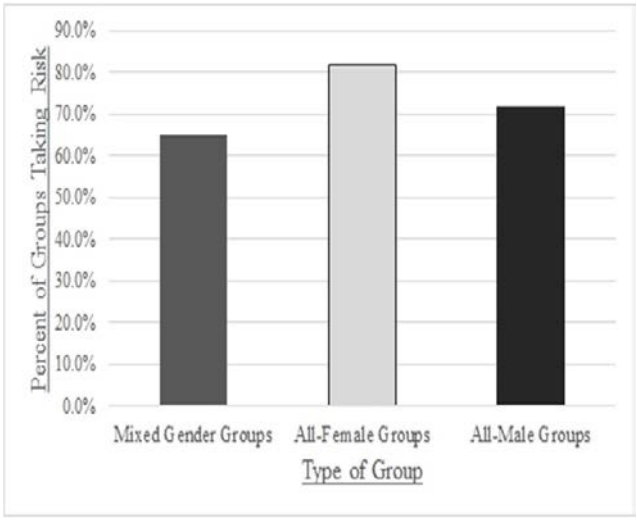

Figure 6: Tendency of different gender groups to exhibit unsafe crossing behavior.

Unsafe crossing behavior - Grouping and gender

Finally, the grouping and gender data was combined and analyzed in relation to the dependent variable of crossing behavior on the level of the individual pedestrian. It was found that women in groups are actually the most likely to exhibit unsafe behavior by disregarding crossing treatments and signals (Figure 7). This is a new and important finding. Solo female pedestrians are, on the other hand, by far the most conservative when crossing the road. Men are fairly consistent in their crossing behavior regardless of their grouping.

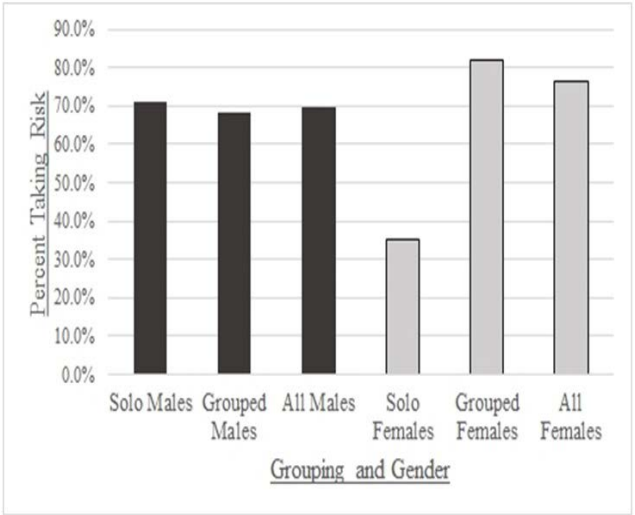

Figure 6: Tendency of different groups and genders to exhibit unsafe crossing behavior.

Logistic regressions were performed to analyze the statistical strength of the tendencies of different combinations of pedestrian groups and genders to exhibit unsafe crossing behavior (Table 3). This model utilized the dichotomous independent variables of gender and whether the individual was in a group regardless of the composition of the larger grouping. Findings suggest that grouped females are significantly more likely to take risks when crossing roadways in the presence of motor vehicles than either grouped males, solo males, or solo females. The relationships of different pedestrian types with solo females were not found to be significant because of small sample sizes of solo female pedestrians. Because of the strength of the grouped females' risk, and the propensity for females to cluster in groups, females are overall more inclined to disregard crossing infrastructure than males are (Table 1).

		More Risk-Averse Pedestrian		
		Solo Females	**Grouped Males**	**Solo Males**
More Risk Prone Pedestrian	**Grouped Males**	0.33 / 1.40^{ns}	na	na
	Solo Males	0.46 / 1.59^{ns}	0.13 / 0.88^{ns}	na
	Grouped Females	1.06 / 2.90 ***	0.73 / 2.07 **	0.60 / 1.82 *

Table 3: Coefficients and odds ratios (B / Exp(B)) for logistic regressions of pedestrians versus their propensity for unsafe crossing behavior.

Note:Independent variable is type of pedestrian (0 = more risk-averse type, 1 = more risk-prone type). Dependent variable is risk (0 = not exhibiting risk, 1 = exhibiting risk).

(Significance: ***p<0.001, **p<0.01, *p<0.05, ns = not significant, na = not applicable)

Discussion

Statistical analysis suggests that there are significant differences in the behaviors of different types of pedestrians. Knowing when and where pedestrians may be likely to exhibit unsafe behavior will allow for planners and engineers to better prepare for unsafe situations and combat one of the leading public health issues of our time. Focusing on design, enforcement, or education with these particular pedestrians in mind may be an effective way to combat the poor safety outcomes of pedestrians in the transportation systems of the developing world.

It is important to first recognize that, according to the analysis, women pedestrians are significantly more likely to form groups than men. Because groups take more risk than solo pedestrians (although not significantly so), the fact that women are apt to form groups has implications when the groupings are further split by gender. Findings from this research suggest that larger groups are more likely to exhibit risky behavior than smaller groups. This is in refutation to research that has previously been performed [15,16]. This positive relationship between group size and inclination towards risk was found to be significant with a logistic regression model. Also, groups consisting completely of females are more likely to exhibit risk than groups that consist completely of males or mixed gender groups. These are new contributions to the understanding of pedestrian crossing behavior in developing countries, and add to the current body of knowledge on the subject.

The most noteworthy finding is that females in groups are actually the most likely pedestrians to exhibit unsafe behavior when crossing the street in the presence of a motor vehicle. This is contrary to past research on the subject, which instead states that males are more willing to take risk [21,22]. Solo female pedestrians are by far the most conservative pedestrians, being very unwilling to take risk. However, grouped female pedestrians are more risky than either grouped males or solo males. This relationship was confirmed to be significant with logistic regressions. Reasons for this may include different grouping dynamics and behavioral patterns of the two genders. Past research has shown that different grouping configurations can influence the weight given to benefits of risk for individuals across a wide spectrum of age [31]. The same dynamics may be at work here. Because so many female pedestrians tend to form groups, females may actually be more inclined to pursue risky behavior than males overall. Males have similar rates of risk-taking whether they are in groups or whether they are solo.

Conclusion

Implications of the above findings are important for the safety of some of the most vulnerable users of transportation systems in the developing world. They are especially important for populations that frequently walk to their destinations such as women and the poor. With considerable numbers of pedestrian traffic fatalities in developing countries, the benefits of identifying situations and groups that are apt to be unsafe may be significant. Now that the populations most at risk have been recognized, locations may be identified that have a particularly high probability of experiencing increased rates of unsafe behavior. For instance, if areas with particularly high levels of female pedestrian groups are identified (such as outside schools), then planners and

engineers can focus on safeguarding those transportation spaces through design and planning. Ensuring that safe and convenient crossing treatments are present may provide a first line of defense against pedestrian injuries and fatalities. A treatment that may be considered is the implementation of appropriate pedestrian phasing for signalization, which would allow for pedestrians to safely cross the street. Traffic calming measures - such as raised crosswalks, pedestrian refuges, or curb extensions with horizontal displacement - may also be explored which would reduce the speed and volume of vehicular traffic at the crossing locations.Also, signage and road markings may be influential in bettering safety outcomes.

In addition to design and planning, education and enforcement may be utilized for the identified populations to further promote safety. With an understanding that certain groups of pedestrians are willing to take risk in the transportation system, special educational efforts may be made to change the behavior of those groups. Education and enforcement may also be aimed at drivers of motor vehicles when passing areas that pedestrians may be expected.

Simulation and modelling are important aspects of transportation planning and design, and may be improved through this enhanced understanding of pedestrian crossing behavior in developing countries. Improved modeling will allow us to more adequately account for safety concerns at vital locations. More realistic simulations of our crossings and intersections will enable designers to solve problems before they occur. Also, although unsafe behavior has been found to be an indicator of undesirable safety outcomes, it would be warranted to explore the relationship between these behaviors and safety outcomes such as injuries or fatalities, which would be a more direct exploration of the impacts on public health.

While the findings in this work are a promising start, more research on the subject is needed. There are other factors that are also important determinants of pedestrian crossing behavior that, although they are not the focus of this study, may better inform future models and improve epidemiological outcomes. Road and traffic conditions have been shown to be important determinants of pedestrian crossing behavior, and would be worthwhile to explore [26,32-34]. Weather and police presence are other factors that impact pedestrian behavior and may be integrated into future models [32,35-37]. Existing literature regarding these variables often focuses on developed countries. Future research would benefit from a developing country perspective.

Strong and significant differences have been found to exist between different groupings and genders of pedestrians in relation to unsafe crossing behavior in a developing country context. Accounting for these differences through modeling, design, education, and enforcement may prove to be an effective method of ensuring the safety of some of our most vulnerable road users, and thereby aid in the prevention of one of the most significant public health issues currently plaguing developing countries.

Acknowledgement

The authors would like to thank the World Resources Institute and EMBARQ India for their support of this work.

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