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Pedestrian signalization and the risk of pedestrian-motor vehicle collisions in Lima, Peru

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Abstract

Safe walking environments are essential for protecting pedestrians and promoting physical activity. In Peru, pedestrians comprise of over three-quarters of road fatality victims. Pedestrian signalization plays an important role managing pedestrian and vehicle traffic and may help improve pedestrian safety. We examined the relationship between pedestrian-motor vehicle collisions and the presence of visible traffic signals, pedestrian signals, and signal timing to determine whether these countermeasures improved pedestrian safety. A matched case-control design was used where the units of study were crossing locations. We randomly sampled 97 control-matched collisions (weighted N=1134) at intersections occurring from October, 2010 to January, 2011 in Lima. Each case-control pair was matched on proximity, street classification, and number of lanes. Sites were visited between February, 2011 and September, 2011. Each analysis

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accounted for sampling weight and matching and was adjusted for vehicle and pedestrian traffic flow, crossing width, and mean vehicle speed. Collisions were more common where a phased pedestrian signal (green or red-lit signal) was present compared to no signalization (odds ratio [OR] 8.88, 95% Confidence Interval [CI] 1.32–59.6). A longer pedestrian-specific signal duration was associated with collision risk (OR 5.31, 95% CI 1.02–9.60 per 15-second interval). Collisions occurred more commonly in the presence of any signalization visible to pedestrians or pedestrian-specific signalization, though these associations were not statistically significant. Signalization efforts were not associated with lower risk for pedestrians; rather, they were associated with an increased risk of pedestrian-vehicle collisions.

Keywords

Pedestrians; Pedestrian Signals; Traffic Signals; Built Environment; Peru; Pedestrian-Motor Vehicle Collisions

1. INTRODUCTION

1.1 Pedestrian injury in Peru

A safe walking environment is key to protecting pedestrians and encouraging physical activity (Rydin *et al.* 2012). In low and middle income-countries (LMICs), walking and public transport still comprises the majority of commutes. Improved pedestrian safety in LMICs is an important public health objective for environmental health, obesity-prevention and injury control. In most LMICs, pedestrians bear much of the road traffic fatality and injury burden. A Global Burden of Disease (GBD, 2010) study estimated that there were nearly half a million pedestrian fatalities in 2010 and 4.5 million years lived with disability due to pedestrian injuries (Lozano *et al.* 2012, Murray *et al.* 2012, Vos *et al.* 2012).

In Peru, pedestrians account for 78% of the country's road traffic fatalities, the highest proportion in the world (World Health Organization 2009). Research on pedestrian-motor vehicle collisions (PMVCs) in Peru has been largely descriptive in nature and has primarily reflected conditions in the capital city of Lima where over 60% of Peru's pedestrian collisions occur (Policía Nacional de Perú 2011). A 2008 report on the ten sites in Lima with the highest annual frequency of PMVCs suggested the possible dangers for pedestrians were inadequate signal timing, conflicts between turning vehicles and crossing pedestrians, failure to use designated bus stops, a lack of marked crosswalks, jaywalking, and the pedestrian right of way not being respected (Secretaría Técnica del Consejo de Transporte de Lima y Callao 2009). A population-based matched case-control study in a low-income district of Lima identified high vehicle volume, high vehicle speed, the presence of street vendors, and the lack of lane demarcation as significant risk factors for child PMVCs (Donroe *et al.* 2008). One hospital-based matched case-control study of child pedestrian injury found that retrospective parental report of poor supervision and the need to cross many streets on the way to school were associated with increased risk (Pernica *et al.* 2012). These two studies were limited by small sample size and possible recall bias. Further, they focused only on child and adolescent pedestrians, and selected controls whose walking habits may have differed from cases. Finally, each study considered only a limited set of environmental factors.

1.2. Pedestrian signalization and pedestrian injury

Pedestrian signalization can improve pedestrian safety by providing information to pedestrians about when it may be safe to make a road crossing (Robertson and Carter 1984, Retting *et al.* 2003, Moudon *et al.* 2008, Ewing and Dumbaugh 2009, Chen *et al.* 2013). Compared to crossings without pedestrian signals, sites with pedestrian signals may reduce pedestrian-vehicle conflicts as well as pedestrian injury and fatality, though this depends on many factors including signal characteristics (e.g., type, placement, and timing), location, time, road design, road characteristics, road user behaviors and road user characteristics. There are many different design considerations associated with pedestrian signals (color only, icons [pedestrian figure, hand sign], with auditory cues, etc.) and these may have an impact on how pedestrians will use the signal (Bradbury *et al.* 2012). Their effectiveness can be improved with modifications such as adding an exclusive pedestrian phase (Zeeger *et al.* 1982, Zaidel and Hocherman 1987), displaying warning signs for pedestrians or drivers (Zeeger *et al.* 1984), and prohibiting turns while pedestrians are allowed to cross (Chadda and Schonfeld 1984).

Pedestrian signals may not always be effective at improving pedestrian safety. A study in Toronto retrospectively examining a decade of city-wide data found a 26% increase in pedestrian collisions after the installation of pedestrian countdown signals, though the researchers were unable to adjust for vehicle or pedestrian volumes (Richmond *et al.* 2013). Road user violations and distractedness may be important factors affecting signal effectiveness (Harruff *et al.* 1998, Tiwari *et al.* 2007, Rosenbloom 2009, Cinnamon *et al.* 2011, Miranda-Moreno and Fernandes 2011, Moudon *et al.* 2011, Thompson *et al.* 2013). Areas with higher densities of children and the elderly may need additional time or signal modification to improve effectiveness at preventing injury (Carmeli *et al.* 2000, Leden *et al.* 2006, Smith *et al.* 2009).

The effect of signalization in low and middle income countries (LMICs), where traffic patterns, pedestrian behaviors, and enforcement may differ, has not been widely evaluated (Híjar *et al.* 2003, Zegeer and Bushell 2012). Traffic signals may be variably disregarded by road users in LMIC settings where enforcement and financial consequences are limited. One study in Bangladesh found a lower odds of pedestrian fatalities on national highways with traffic lights or police compared to those with no signalization or stop signs (Sarkar *et al.* 2011) as did another in Taiwan (Doong and Lai 2012). Adolescents in Kathmandu were more likely to report having had a pedestrian injury if they did not typically wait for the green phase to cross (Poudel-Tandukar *et al.* 2007). We found no studies specifically examining the relationship between pedestrian signals and injury in LMICs after a thorough literature search.

The Municipality of Lima and constituent municipal districts have employed various types of automated traffic signals for pedestrians (Secretaría Técnica del Consejo de Transporte de Lima y Callao 2008, 2009). There were principally two types of phased pedestrian signals in Lima. One type alternated between a motionless green or red figure (Figure 1a) and the other includes a countdown for both vehicle and pedestrian traffic with a moving pedestrian figure (Figures 1b and 1c). The presence of pedestrian-specific signals, however, was the exception. If a traffic light was present, it was typically placed such that it was visible only to motorists entering an intersection and not to pedestrians (Secretaría Técnica del Consejo de Transporte de Lima y Callao 2009). In the periphery of Lima where most housing developments had been established informally, there was little signalization for vehicles or pedestrians at intersections (including stop signs), even on arterial roads (Secretaría Técnica del Consejo de Transporte de Lima y Callao 2009).

1.3. Study Objectives

Due to the paucity of research on the effectiveness of traffic and pedestrian signalization in LMICs, we sought to evaluate their relationship with the occurrence of pedestrian-motor vehicle collisions in Lima, Peru. Our primary objective was to evaluate the risk of police-reported pedestrian-motor vehicle collisions ("collisions") at intersections with pedestrian signals compared to unsignalized intersections in Lima, Peru. We hypothesized that intersections with pedestrian signals would be less likely to have pedestrian collisions than sites with no signalization. Because of the variability of signal types and placement, we were also interested in determining whether different types of traffic signals had a lower odds of collisions compared to unsignalized sites. Additionally, we evaluated the effect of signal timing on the risk of pedestrian collisions.

2. MATERIALS AND METHODS

2.1 Study Design and Participants

We conducted a matched case-control design of pedestrian collisions in Lima, Peru, similar to a US study of pedestrian risk at crosswalks (Koepsell *et al.* 2002). The unit of analysis was a pedestrian crossing area at each intersection. Cases were pedestrian crossings at road intersections where the *Policía Nacional del Perú* (National Police of Peru) reported that a pedestrian collision had occurred between October 1, 2010 and January 15, 2011. Controls were pedestrian crossings in the proximity of case sites that matched the case site's road classification and number of lanes. A case index crossing area was defined as a 10-meter section around a reported pedestrian collision. Control index crossings were also 10-meter sections around a crossing in the control intersection that had the same position in an intersection as the matching case index crossing. When the police report lacked sufficient detail to determine the exact location within an intersection (14% of cases), we randomly selected a crossing (Figure 2) on the road on which the incident occurred as the index crossing. The study protocol was approved by institutional review boards at the University of Washington and *Universidad Peruana Cayetano Heredia*.

Due to the high frequency of pedestrian collisions in Lima (over 13,000 annually), we used a two-stage cluster-sampling scheme to select a representative set of incidents and sites in order to report population-level estimates of pedestrian collision risk due to the built environment. The first stage randomly selected 11 commissaries from the 106 commissaries in metropolitan Lima. Random selection was based on commissary-reported collisions in 2006 as the sampling frame where the probability of a commissary being selected was proportional to the number of collisions reported. We visited selected commissaries in January and February 2011 to collect records any motor vehicle collision involving a pedestrian that had occurred between October 1, 2010 and January 15, 2011. After visiting 11 selected commissaries we determined that we had collected a sufficient number of records to meet estimated sample size requirements. In the second stage of sampling we randomly sampled 80% of recorded collisions within each commissary. We excluded cases that were outside the commissary limits, misclassified as pedestrian (e.g., cyclist) intentional collisions, or those missing necessary information for the study (Figure 3). For the safety of research staff, we excluded incidents that occurred from 8 PM to 6 AM and other potentially dangerous sites (by dangerous we mean in terms of criminality and risk of assault to study staff, not traffic safety).

We used a risk set sampling method to select one matched control for each case (Rodrigues and Kirkwood 1990, Langholz and Goldstein 1996, Koepsell *et al.* 2002). Risk set sampling is an epidemiological method of evaluating the risk of an outcome in a population (pedestrian crossing locations in this study) by grouping together members of the population into matched sets. At the moment a member of a risk set becomes ill and becomes a case (a pedestrian collision in this study), one or more outcome-free members from the risk set can be randomly selected as the matched control for the case. A control was incorporated into each risk by matching nearby street-crossing sites to each case by proximity, number of lanes and road classification. Three geographical tools were used to find potential controls near each case. The website of *Guia Calles del Perú* (http://www.guiacalles.com) provided street directory and address information for Lima and was used to locate case addresses. A marker for each case was then created in Google Earth 6 (Google Inc., Mountain View, CA). Satellite images from Google Earth were used to visually identify potential controls based on the number of lanes and the direction of vehicle traffic (one-way or two-way) for each site. Initially a 500 meter radius area around each case site was searched and this radius was expanded repeatedly by 100 meters until at least one suitable match was found. We identified at least one control for every case within a maximum 1000-meter radius. We assigned road classifications using a geodatabase provided by the *Consejo de Transportes de Lima y Callao* (CTLC; Transportation Council of Lima and Callao) that included a road network layer. Using ArcGIS 10.0 (ESRI, Redlands, CA), we used the road network layer to classify cases and their potential controls as highway, arterial, collector, local/residential, non-connecting, and other. Finally, one control from the risk set for each case was randomly selected for a visit.

Because road conditions, traffic, and other factors can change over time, a pedestrian crossing at an intersection could be part of future risk sets and could be sampled as a control or become a case again. Six intersections were visited at different times to obtain data as both case and control sites. Additionally, nine control intersections and 12 case intersections were visited more than once.

2.2 Measures

The study outcome was the presence or absence of a police-reported pedestrian-motor vehicle collision at a crossing location. The primary exposures in this analysis were the presence of any visible traffic control signal (phased vehicle signal, stop or yield sign, or transit police directing traffic), the presence of any pedestrian signal, the type of pedestrian signal (stationary red/green figure phased signal or regressive countdown signal with a moving green figure or stationary red figure, Figure 1), the duration of the green and red phases of a traffic signal if present, the duration of the phases of a pedestrian signal if present, and whether the pedestrian signal timing allowed pedestrians to cross at the recommended crossing rate of 3.5 feet per second (National Committee on Uniform Traffic Control Devices 2009). Signal visibility was defined as a signal being visible to pedestrians from at least one side of the crossing area without any permanent barriers blocking its view. Visibility was an issue to consider because at times signals were not visible to pedestrians due to permanently placed objects blocking their view (e.g., trees, other signs, or utility poles). Pedestrian and vehicle flow, vehicle speed, presence of crosswalk markings, crosswalk marking condition, crossing distance (meters), number of radiating roads, and the number of crossing segments (*e.g.*, subdivisions of the crossing areas where pedestrians may pause outside of vehicle traffic such as a pedestrian refuge or median divider, Figure 2) were measured as described below.

2.3 Procedures

The regional leadership of the *Policía Nacional del Perú* (National Police of Peru) approved the use of its data for this study. During sampling of potential case sites, a liaison officer accompanied study staff at the commissaries in order to facilitate access and to assist with accessing and recording data. Commissaries were visited during January and February, 2011 to retrospectively collect data on pedestrian collisions that occurred from October 1, 2010 to January 15, 2011.

The date and time of site visits to collect data depended on the day of the week and time of the case incident. Both case and control sites were visited on any weekday if the original incident occurred on a weekday and similarly for incidents that occurred on weekends. We collected data at sites within an hour of the time of the occurrence of the case incident. For example, if an incident had occurred on a Wednesday at 1:20 PM we would visit that site and its control on a weekday between 12:20 PM and 2:20 PM. Sites that were cases or controls more than once were visited again at the appropriate time to record vehicle and pedestrian flow, signal timing and speed. Physically stable factors were measured once since they did not change during the study period. At each site we recorded 10 minutes of vehicle and pedestrian activity at the crossing area and photographed the site area. Using a portable speed gun vehicle speeds were recorded for each direction of traffic for 10 minutes or until 25 vehicles were observed. We also measured road geometry and physical characteristics, diagrammed site features, and measured signal timing with a stopwatch. Each field worker was trained to collect all data types. All field workers were blinded to case and control status. Site videos were coded by trained research assistants, who recorded the total number of vehicles passing through the observed crossing in both directions and the number of pedestrians crossing it.

2.4 Statistical Analysis

We assessed the relationship between case and control status (i.e., the occurrence of pedestrian collision or not) and the presence of primary exposures of interest while adjusting for potential confounding from other characteristics. We used conditional logistic regression for all analyses to account for matching to calculate odds ratios (ORs), 95% confidence intervals (CI) and *P* values (see online supplement). To determine the relationship between the main exposure (signalization) and outcome, we examined univariate associations and then tested these relationships in models with potential confounders. Continuous variables such as pedestrian and vehicle flow were tested in fractional polynomial models to assess whether they were best fit as linear variables or in a nonlinear form.(Royston and Altman 1994) A single linear term for each of these variables was determined to be the best fit in all models. All analyses were performed with Stata 11 (STATA Corp, College Station, TX, USA) and accounted for the sampling scheme using weighted estimates (Levy and Lemeshow 2008).

3. RESULTS

There were 406 pedestrian-vehicle collisions involving 426 pedestrians and 417 drivers at the 11 sampled commissaries during the surveillance period (Figure 3). There were seven pedestrian fatalities, though they were not among the visited sites due to their occurrence between 8 PM and 6 AM. We visited 103 sites. Complete data were available for 97 sites at intersections. Most of the examined collisions occurred on arterial (41%) or collector (41%) roads (Table 1). Slightly more than half of pedestrians were male (53%), though the drivers of vehicles striking the pedestrians were nearly all male (91%). Most vehicles involved in collisions were passenger vehicles (64%) or motorcycles (21%). Suspected alcohol use was rarely mentioned in official reports, though alcohol use was unknown for most cases as there was no systematic testing or reporting by the police.

The 97 cases represented 1,134 pedestrian-motor vehicle collisions at intersections meeting study criteria throughout metropolitan Lima over a 3.5-month period. There was a significant difference in the number of road legs (Figure 2) within an intersection (p=0.014, Table 2). Case sites had somewhat higher mean vehicle and pedestrian flows than control sites, but this difference was not significant when survey data were weighted. No other significant differences were observed between case and control site road characteristics, indicating adequate matching.

Case sites were more likely to have any type of traffic signal visible to pedestrians on either or both sides of the crossing than were controls sites (OR 3.14, 95% 0.54–18.2), though this was not statistically significant (Table 3). Few intersections had a stop sign on one of the legs (3%) and no index crossing area was controlled by a stop sign. Sites with any type of pedestrian signal had an elevated risk for a collision compared to sites without signaling (38% vs. 28%, P value=0.205). A combined stationary pedestrian figure and phased vehicle signal (Figure 1) had a higher odds of a pedestrian collision (OR 11.3, 95% CI 2.86–44.5). At sites with a pedestrian signal, a longer “green” phase was associated with increased collision risk (OR 1.19 per second, 95% CI 1.15–1.23). Sites with a police officer present were less likely to have a collision compared to unattended sites.

Associations observed in univariate analysis remained after adjusting for potential confounders such as vehicle and pedestrian flow in multivariable analysis (Table 4). Sites with a stationary figure pedestrian signal were more likely to have a collision (OR 8.88, 95% CI 1.32–59.6). Longer signal "green" phase crossing time had a five-fold increase in the odds of collisions for each 15-second interval increase in green duration (OR 5.31, 95% CI 1.02–9.60). The presence of other types of signalization tended towards higher risk for pedestrians, though the associations were not statistically significant. While signalization did not demonstrate an association with safety, the presence of transit police to regulate traffic appeared to be strongly associated with lower risk of a collision compared to sites with no regulation (OR 0.05, 95% CI 0.004–0.60), though there were few sites that had police present.

4. DISCUSSION

Our results suggest that as of 2011 pedestrian signalization in Lima, Peru was not associated with a lower risk of pedestrian collision, and, paradoxically, was sometimes associated with a higher risk for collision compared to sites that lacked traffic signals. Prolonged crossing times and signals with a stationary pedestrian figure failed to reduce collision risk for pedestrians.

These results were contrary to our initial hypothesis that signalization for pedestrians would reduce the risk of pedestrian-motor vehicle collisions, as has been in found in some studies in high-income countries (Retting *et al.* 2003, Chen *et al.* 2013). Our findings suggested that such interventions may not be as effective in LMICs, perhaps due to an enforcement climate where road users circumvent or ignore safety features (Khan *et al.* 1999, Híjar *et al.* 2003, Nakitto *et al.* 2008). It is possible that the absence of a signal results in pedestrians and drivers being more cautious (Koepsell *et al.* 2002, Mitman *et al.* 2008).

While both drivers and pedestrians are expected to adhere to traffic signalization, this is less often the case in LMICs compared to high-income countries (Khan *et al.* 1999, Hamed 2001, Híjar *et al.* 2003, Ren *et al.* 2011). Crossing behavior could be affected by signalization in several ways. Elevated collision risk was most pronounced for prolonged signal crossing times, where 15-second longer crossing time was associated with a 5.3-fold increase in risk (95% CI 1.02–9.60). Longer crossing times may have contributed to both pedestrian and driver impatience leading to risky behaviors. Previous research indicates that a longer red phase for pedestrians can lead to pedestrian impatience and earlier crossing (Tiwari *et al.* 2007, Bradbury *et al.* 2012). A longer crossing time may have also resulted in more pedestrians crossing in the latter part of the signal and getting trapped in the crossing area. Sites with multiple crossing segments may have compounded pedestrian risk if pedestrians become impatient while waiting on a refuge and cross against the signal, as was observed in a Jordanian study (Hamed 2001).

The association of pedestrian signals with pedestrian collisions could also be related to the type and operation of the pedestrian signals used in Lima. Some previous studies have indicated that signals with an exclusive pedestrian phase may be more effective at reducing pedestrian collisions than standard signals, where the time of vehicle and pedestrian signals are paired (Zeeger *et al.* 1982, Van Houten *et al.* 2000). The latter situation may lead to pedestrian-vehicle conflicts due to turning vehicles (Chadda and Schonfeld 1984, Roudsari *et al.* 2006). In Lima, few intersections have an exclusive left-turn phase, thus many turning vehicles compete with pedestrians crossing in the path of the turning vehicle. There is evidence from at least one study that may indicate that pedestrian countdown signals like those observed in this study may be have a slightly higher risk of pedestrian collisions (Richmond *et al.* 2013), though other smaller studies have observed a potential improvement in pedestrian safety with these signals (Schattler *et al.* 2007, Nambisan and Karkee 2010, Pulugurtha *et al.* 2010).

There were some study limitations as it is recognized that police-reported data are not always ideal for research (Secretaría Técnica del Consejo de Transporte de Lima y Callao 2011). Police record information relevant to their duties and some data were incomplete, such as alcohol use by drivers or pedestrians. We attempted to minimize bias by using police data only to identify locations of collisions regardless of the severity of the incident or injuries to the pedestrian. We excluded 26% of police-reported collisions due to a nighttime occurrence or other safety concerns for study staff, thus our results should only be interpreted for daytime collisions. Nighttime collisions are likely influenced by factors other than signalization, such as alcohol use by drivers and pedestrians. It is possible as well that the police did not record every pedestrian collision, which could affect our estimates depending on how they are related to our exposure measures. There are no data available to estimate the degree of bias from this potential limitation.

The limited period of observed pedestrian and vehicle flow (10 minutes) could contribute to residual confounding. Prior traffic research has used longer observation periods to better characterize these variables. Additionally, pedestrian and vehicle flow data may have differed from traffic characteristics at the time of the incident. To explore this question, we used external data from the Lima transport agency to compare official reports of vehicle and pedestrian flow for three of our study sites. For these sites, observed flow data was similar to the external data (data not shown).

Finally, up to 10 months had elapsed between the collision date and data collection. To explore the possible impact of this time difference, Google Earth archival satellite images were retrieved for a random sample of 10% of the cases and controls to assess any major visible changes to the sites during the intervening period. No major changes (such as new traffic lights or geometrical changes) were observed, though some had fainter paint markings than earlier images and a few had newer paint markings than earlier noted.

5. CONCLUSIONS

Pedestrian signalization in Lima was not associated with pedestrian safety. Our study suggests that the presence of police directing traffic appeared to be beneficial to pedestrians, though traffic officers were not widely observed at study sites. Lima passed a pedestrian jaywalking law in November of 2010, and 22,000 tickets were issued in its first year (2.8 per 1,000 residents).

Little is known about whether ticketing for vehicle infractions influences the safety of walkers. Future research should examine the role of enforcement on pedestrian safety in LMICs (Ebel *et al.* 2009, Nasar and Troyer 2013). The WHO and UN Road Safety Collaboration have created several manuals, including one on pedestrians, that provide guidance on interventions that may help improve road safety (Younger *et al.* 2008). Our study also suggests that careful consideration of strategies to encourage vehicle and pedestrian compliance with signalization are important.

Policies and interventions to improve safety through urban planning require evaluation specific to the local context and should ensure equitable access and safety across the population (Rydin *et al.* 2012). These policies should have the goal of increasing active transportation that ensure pedestrian safety in the walking environment in any major urban area where pedestrians and vehicles interact.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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HIGHLIGHTS

- We examine pedestrian-motor vehicle collisions and signalization in Lima, Peru
- Some types of pedestrian signals were associated pedestrian collisions
- Longer crossing times for pedestrians were associated with pedestrian collisions
- Lack of signal effectiveness may be due to low compliance with signalization

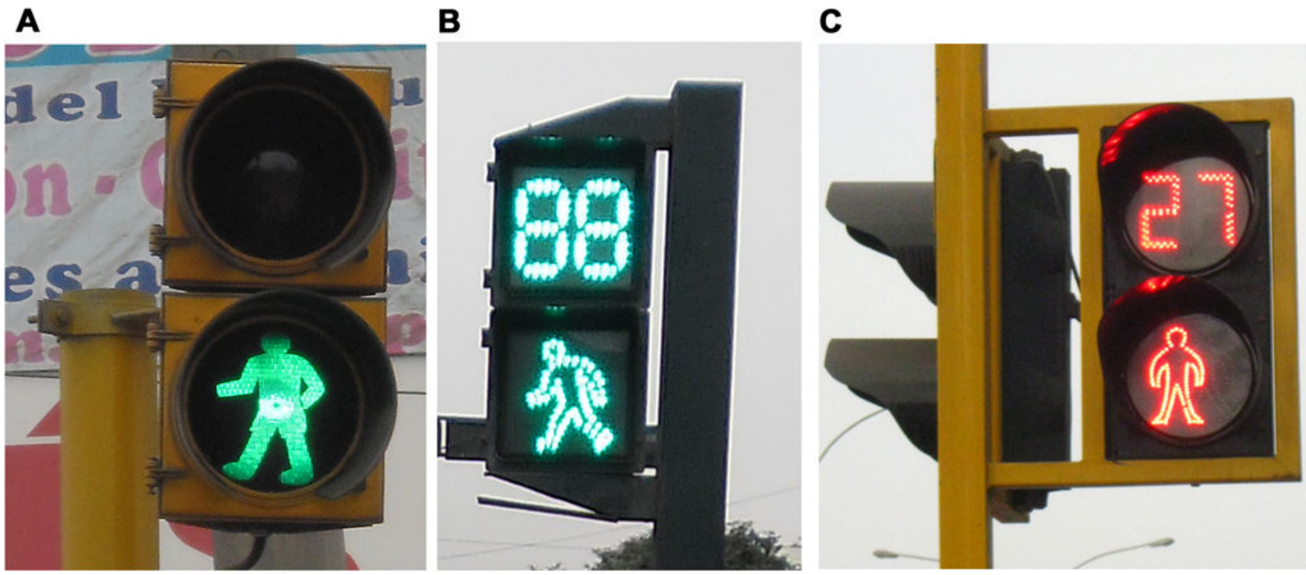

Figure 1. Pedestrian Signal Types

There are a variety of pedestrian signals in Lima, but can be classified into two groups: stationary and countdown. A) Stationary pedestrian signal; B) Countdown pedestrian signal with a moving figure. C) Another example of countdown pedestrian signal with a moving figure.

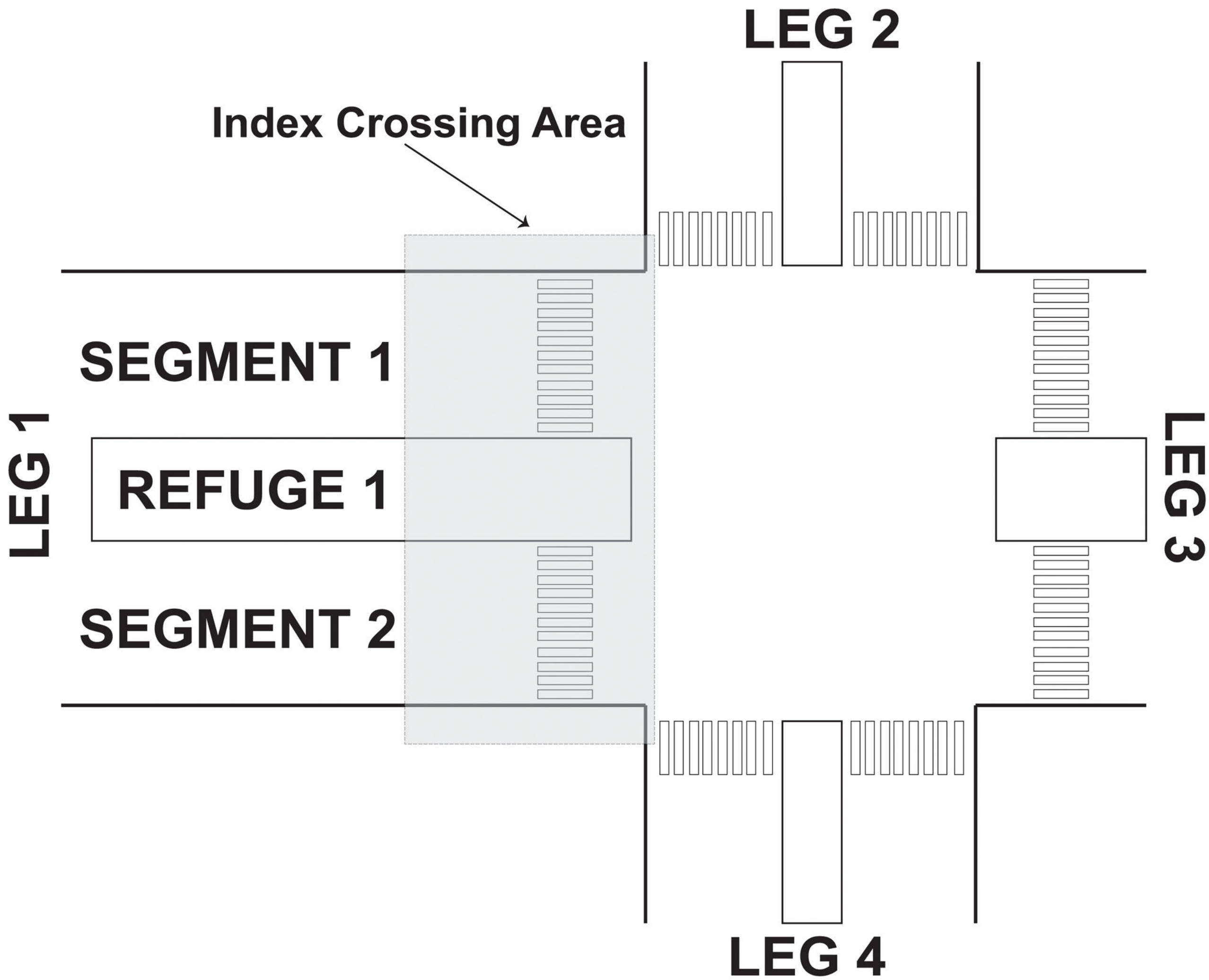

Figure 2. Road Geometry Definitions

The **index crossing** area was the area under study observation at an in intersection. A **leg** was an intersecting road at an intersection. A **refuge** was an area that provided a space for pedestrians to pause their crossing. A **segment** was a subdivision of the crossing area created by a refuge.

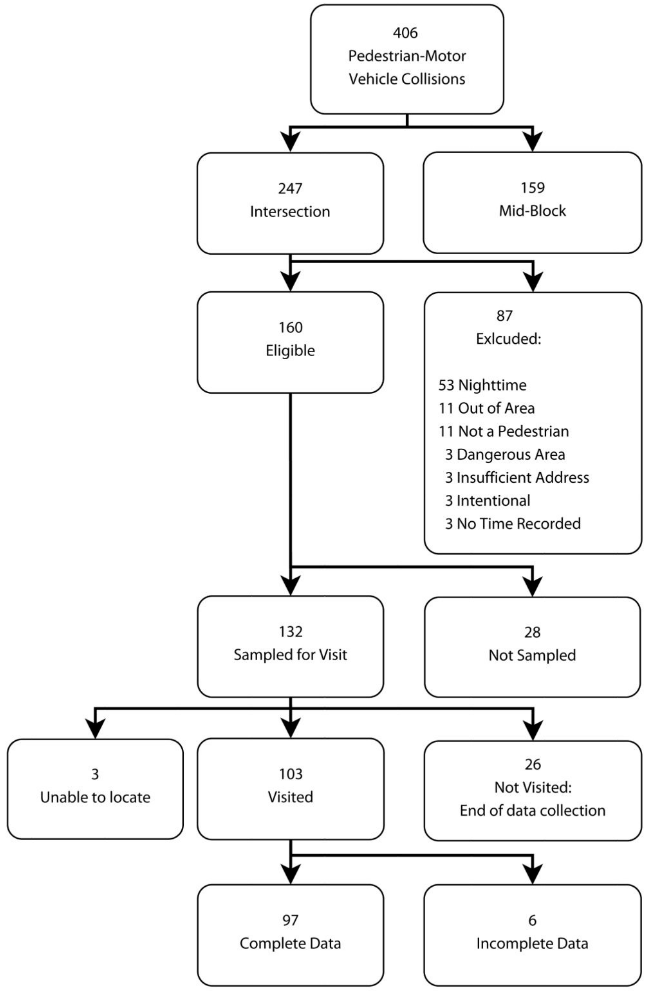

Figure 3. Flowchart of Pedestrian-Motor Vehicle Collisions at Intersections for Study Inclusion

Table 1

Characteristics of police reported pedestrian-motor vehicle collisions at intersections in the analysis (n=97).

	%
Road Type	
Arterial	41
Collector	41
Local	11
Non-Connecting	1
Highway	5
Pedestrian Sex Male	53
Index Driver Sex	
Male	91
Female	4
Missing	5
Index Pedestrian Age (Years)	
<10	6
10–18	7
19–25	13
26–65	54
66–95	18
Missing	2
Index Driver Age	
<26	13
26–60	72
61–78	5
Missing	9
Type of Vehicle	
Passenger Vehicles	*64*
2- or 4-door sedan	33
Light Truck/Sport Utility Vehicle	12
Station Wagon	16
Compact	2
2- or 3- Wheeled Motorcycles	*21*
Motorcycle	11
Motorcycle taxi[a]	9
Public Transit Vehicles	*14*
Full-size bus (Omnibus)	9
Minibus (Coaster)	1
Van-Converted Minibus (Combi)	4
Missing	*1*
Suspected Pedestrian Alcohol Use[b]	4
Suspected Driver Alcohol Use[b]	2

	%
Weekday Occurrence	85

[a] A motorcycle taxi is a three-wheeled, motorized cabin cycle, also known as an auto rickshaw, mototaxi or motorcar.

[b] Not all drivers or victims are consistently tested, nor are results consistently recorded except perhaps when positive. The record sometimes had a BAC reported, and sometimes just the reported suspicion of alcohol use.

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Table 2

Characteristics of the intersection and index crossing for cases and controls, unweighted and weighted.

	Unweighted			Weighted		
	Cases N=97 %	Controls N=97 N %	P Value*	Cases N=1134 %	Controls N=1134 %	P Value*
No. of Legs			0.170			**0.014**
3	33	28		39	29	
4	67	70		61	70	
5	0	2		0	1	
No. of Segments			0.385			0.366
1	31	28		32	29	
2	54	57		58	62	
3	8	7		8	7	
4	7	8		2	3	
No. of lanes	4.4 (2.1)	4.5 (2.0)	0.550	4.2 (2.0)	4.4 (1.9)	0.322
Crossing Width (Meters), Mean (SD)	21.2 (13.4)	20.9 (13.3)	0.756	17.9 (10.0)	18.8 (10.7)	0.520
Any refuge			0.327			0.577
No	33	30		40	44	
Yes	67	70		59	56	
Width of Refuges (Meters), Mean (SD)	8.3 (7.7)	8.5 (7.3)	0.380	5.2 (4.5)	5.7 (5.2)	0.680
Surface Material			0.484			0.448
Asphalt	95	93		88	87	
Concrete or Brick	5	7		12	1	
Surface Condition			0.913			0.645
Excellent	4	8		10	14	
Good	54	49		47	44	
Fair	32	29		33	33	
Poor	10	13		10	9	
Marked Crosswalk			0.339			0.073
No	39	44		34	41	
Yes	61	56		65	59	

	Unweighted			Weighted		
	Cases N=97 %	**Controls N=97 N %**	**P Value***	**Cases N=1134 %**	**Controls N=1134 %**	**P Value***
Crosswalk Marking Visibility			0.567			0.303
Unmarked	39	44		35	41	
Good Visibility	24	21		20	21	
Fading	23	21		25	19	
Almost Gone	14	14		20	18	
Vehicles per hour, Mean (SD)	1715 (967)	1553 (1001)	0.053	1677 (951)	1429 (868)	0.114
Pedestrians per hour, Mean (SD)	436 (505)	305 (404)	**0.007**	360 (396)	285 (378)	0.331
Mean Speed (KPH), Mean (SD)	33.7 (6.1)	34 (6.0)	0.442	31.9 (5.8)	33.8 (5.7)	0.230
Max Speed (KPH), Mean (SD)	55.9 (28.2)	54.4 (10.2)	0.625	50.0 (9.8)	53.3 (9.4)	0.936

* P Value was a test for null hypothesis of equal odds ratios between categories.

Table 3

Univariate analysis of pedestrian-motor vehicle risk by signalization characteristics on the index crossing for cases and controls, unweighted and weighted. Frequencies and proportions unless otherwise noted.

	Unweighted				Weighted			
	Cases N=97 %	Controls N=97 %	OR (95% CI)	P-Value	Cases N=1134 %	Controls N=1134 %	OR (95% CI)	P-Value
Any visible signal				0.058				0.178
No	53	62	Ref.		53	63	Ref.	
Yes	45	38	2.50 (0.97–6.44)		47	37	3.14 (0.54–18.2)	
Traffic Regulation[a]				0.331[e]				**0.007**[e]
None	52	56	Ref.		48	54	Ref.	
Phased Signal	31	26	2.11 (0.71–6.25)		30	27	1.75 (0.49–6.20)	
Countdown Signal	13	16	0.84 (0.28–2.48)		19	17	1.76 (0.27–11.4)	
Police	2	3	0.44 (0.36–5.48)		2	2	0.72 (0.22–2.33)	
Phased Signal Duration[b]								
Green (seconds), *Mean (SD)*	51.4 (20.0)	45.9 (15.5)	1.02 (0.99–1.06)	0.259	48.9 (16.7)	44.4 (12.9)	1.02 (0.98–1.08)	0.287
Red (Seconds), *Mean (SD)*	47.8 (28.6)	45.6 (16.8)	1.01 (0.98–1.04)	0.527	47.7 (26.3)	44.1 (15.2)	1.02 (0.96–1.08)	0.544
Any Pedestrian Signal				0.416				0.205
No	63	67	Ref.		62	72	Ref.	
Yes	37	33	1.40 (0.62–3.15)		38	28	2.51 (0.60–10.5)	
Type of Pedestrian Signal				0.221[e]				**0.026**[e]
None	53	62	Ref.		53	63	Ref.	
Stationary Figure	26	18	5.80 (1.32–25.6)		20	11	11.3 (2.86–44.5)	
Countdown & Figure	12	16	1.16 (0.39–3.49)		19	17	1.76 (0.23–13.6)	
Vehicle Signal	7	3	4.58 (0.90–23.4)		6	7	1.86 (0.20–17.3)	
Transit Police	2	2	1.08 (0.06–18.2)		2	2	1.33 (0.48–3.68)	
Pedestrian Signal Duration[c]								
Green (Seconds), *Mean (SD)*	44.1 (21.8)	39.0 (13.1)	1.21 (1.02–1.44)	**0.031**	38.4 (20.6)	35.5 (14.5)	1.19 (1.15–1.23)	**<0.001**
Red (Seconds), *Mean (SD)*	63.6 (31.3)	57.2 (16.5)	1.02 (0.98–1.06)	0.247	63.2 (27.9)	53.4 (15.3)	1.04 (0.98–1.10)	0.236
Allowed Crossing Rate <3.5 Ft/Sec[d]	80	70	4.00 (0.45–35.8)	0.215	94	73	9.14 (0.46–182)	0.127

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[a]Stop signs or markings were excluded due to only being present at 2 cases and no controls.

[b]N=29 unweighted matched pairs and 205 weighted matched pairs, where both case and control have phased vehicle signals

[c]N=21 unweighted matched pairs, N=115 weighted matched pairs, where both case and control have pedestrian signals

[d]The allowed crossing rate was how fast a pedestrian must cross the total crossing distance in the allowed green pedestrian signal time, measured in feet per second

[e]P Value was a test for null hypothesis of equal odds ratios between categories.

Table 4

Multivariable analysis evaluating the association of signalization characteristics with case-control status.

	Unweighted		Weighted	
	OR (95% CI)	**P-Value**	**OR (95% CI)**	**P-Value**
Any Visible Signal[a]	2.89 (0.76–10.96)	0.119	3.67 (0.34–39.7)	0.252
Traffic Regulation[b]		0.145		0.062
None	Ref		Ref	
Phased Signal	1.50 (0.43–5.23)		1.71 (0.43–6.74)	
Countdown Signal	0.73 (0.20–2.64)		1.51 (0.14–16.8)	
Police	0.05 (0.002–1.26)		0.05 (0.004–0.60)	
Phased Signal Duration				
Green (Seconds)[c]	1.04 (0.99–1.09)	0.107	1.07 (0.98–1.17)	0.100
Red (Seconds)[c]	1.00 (0.97–1.04)	0.871	1.00 (0.93–1.08)	0.990
Any Pedestrian Signal[d]	1.11 (0.44–2.78)	0.825	2.26 (0.38–13.3)	0.330
Type of Pedestrian Signal[d]		0.068		0.113
No Signalization	Ref.		Ref.	
Stationary Figure	5.55 (0.95–32.3)		8.88 (1.32–59.6)	
Countdown & Figure	0.73 (0.21–2.50)		1.53 (0.09–27.0)	
Vehicle Signal	5.51 (0.83–36.6)		2.52 (0.22–29.2)	
Transit Police	0.12 (0.004–3.62)		0.09 (0.01–1.02)	
Pedestrian Signal Duration				
Green (Seconds)[c]	1.30 (1.02–1.67)	**0.035**	1.42 (1.07–1.90)	**0.024**
Red (Seconds)[c]	1.26 (0.96–1.66)	0.099	1.74 (0.56–5.40)	0.267
Crossing Rate<3.5 Ft/Sec[e]	5.09 (0.36–71.9)	0.229	8.28 (0.02–3786)	0.449

[a]Adjusted for Total Width, Vehicles per Hour, Pedestrians per Hour, Marked Crosswalk, Mean Vehicle Speed and Number of Segments

[b]Adjusted for Total Width, Vehicles per Hour, Pedestrians per Hour, Mean Vehicle Speed and Number of Segments

[c]Adjusted for Total Width, Vehicles per Hour, Pedestrians per Hour, and Mean Vehicle Speed

[d]Adjusted for Total Width, Vehicles per Hour, Pedestrians per Hour, and Number of Segments

[e]Adjusted for Vehicles per Hour, Pedestrians per Hour, and Mean Vehicle Speed