Dissertation Proposal:
Examining Correlates of Pedestrian Crash Risk and Assessing the Effectiveness of a Community-Based Intervention to Prevent Pedestrian Injury

Department of Epidemiology, School of Public Health
University of North Carolina at Chapel Hill
Chapel Hill, NC
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Doctoral Student:	Laura Sandt, MRP Phone: 512-590-9650 (cell); 919-962-2358 (work) Email: sandt@hsrc.unc.edu
Dissertation Committee:	Steve Marshall, PhD (Chair) Susan Ennett, PhD Kelly Evenson, PhD Whitney Robinson, PhD, MSPH Daniel Rodriguez, PhD

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1. OVERVIEW

The public health burden of unintentional injury is high. Risk of pedestrian injury or fatality from a motor-vehicle collision (MVC) in North Carolina is a significant and often overlooked problem, particularly for vulnerable populations such as minorities or low-income neighborhood residents. Little research has been done to date to examine the epidemiology of pedestrian crashes and the distribution of crashes in disadvantaged neighborhoods. North Carolina is unique among states in that it hosts a statewide Emergency Department (ED) database containing information on pedestrian injury, as well as a statewide database of detailed and geo-coded (or spatially located) pedestrian crash data. These previously untapped data resources can provide a wealth of information regarding the epidemiology of pedestrian crashes and crash correlates, which can be useful to those planning public health interventions to address such crashes.

Similarly, there is limited research available that quantifies the effectiveness of pedestrian injury prevention interventions. In North Carolina, a pedestrian injury prevention intervention, called Watch for Me NC, is currently taking place that aims to reduce pedestrian crashes and injuries through a community-based program involving a comprehensive set of education, outreach, and law enforcement measures. This effort provides a timely opportunity to examine the effectiveness of comprehensive, theory-driven interventions. Such research can aid in predicting the likely effectiveness of pedestrian interventions, and ultimately, assist localities in planning and evaluating such programs.

The purpose of this dissertation is to 1) contribute to the literature on the descriptive epidemiology of pedestrian-motor vehicle crashes, and 2) to perform a rigorous scientific evaluation of a safety intervention to reduce pedestrian crashes and injuries through education, enforcement, and officer training and capacity-building. The following sections provide a context for this research and summary of prior efforts in this area, as well as a detailed approach to how these aims will be accomplished.

2. BACKGROUND

2.1 Magnitude of Pedestrian Injuries and Fatalities

Injury, and in particular traffic-related injury, is a leading cause of morbidity and disability, contributing to loss of productive years and accounting for a considerable amount of the cost to the US health system (Finkelstein et al., 2006). Relative to other road users, pedestrians involved in a crash are more likely to experience severe injury and pedestrian crashes are considered the most lethal blunt-trauma mechanism of injury (Maybury, 2010). In a review of more than 500,000 blunt trauma patients in the National Trauma Data Bank from 2001 to 2005, Haider et al. (2009) found that the mean injury severity score, mortality rate, and extremity injury were highest among pedestrians struck by motor vehicles.

In North Carolina (NC), there are 2,200 pedestrian-involved MVCs each year, leading to between 150 and 200 pedestrian deaths and an additional 500 serious injuries (UNC, 2011). The geographic focus of this study, the Triangle region of NC, has been identified as a particularly high-risk region of the country and the state. In a 2011 report, the Raleigh-Cary region had the 13th highest pedestrian danger index (a measure of total pedestrian fatalities, fatalities per capita, and walking rates) out of the 52 metropolitan areas in the US with over 1 million people (Ernst, 2011).

In both the United States and North Carolina, pedestrians represent 13% of all motor vehicle traffic (MVC) fatalities. According to the latest data available from the National Highway Traffic Safety Administration (NHTSA, 2013), in 2011 4,432 pedestrians were killed in MVCs in the US. An additional 69,000 pedestrians were estimated to have been injured. In view of the magnitude of this problem, the

Centers for Disease Control and Prevention (CDC) recognize transportation-related injuries, and specifically pedestrian safety, as a primary research interest. A key injury research priority is to evaluate the effectiveness of behavioral and environmental strategies to prevent pedestrian injuries (CDC, 2009).

2.1.1 Vulnerable Populations

Minority populations in low-resource communities tend to bear a significant portion of general highway crash and overall injury burden (Chen et al., 2011; Cubbin, 2002; Ernst, 2011; Kravetz and Noland, 2012; Maybury et al., 2010; Morency et al., 2012; Loukaitou-Sideris and Liggett, 2007). Minority groups also are overrepresented in pedestrian crashes and fatalities. While African Americans represent only 12% of the US population, African Americans are, on average, involved in more than 20% of the pedestrian fatalities (Chen, 2011). Ernst (2011) used Centers for Disease Control and Prevention (CDC) data to examine pedestrian fatalities from 2000 to 2007 and found that the pedestrian fatality rate per 100,000 persons was 1.38 for non-Hispanic Whites, 2.23 for Hispanics, and 2.39 for African Americans. In a pilot study conducted by UNC-HSRC, African Americans were significantly over-represented in pedestrian crashes in Charlotte, Durham, and Wilson, NC. In these communities, the proportion of African Americans in the general population was 33, 40, and 48%, respectively, while African Americans made up 52, 59, and 54% of the pedestrians hit by motor-vehicles in a five-year period (Sandt, 2011).

The reasons for these disparities may be due to the fact that minority and low-income groups are more likely to rely on walking and transit use and have lower rates of car ownership (Ernst, 2011; Berube et al., 2006). While only 4.6% of White, non-Hispanic households in the US does not have access to a vehicle, nearly 14% of Hispanic households and 20% of African American households do not have access to a vehicle (Berube et al., 2006). Similarly, more than 19% of low-income households (making less than $25,000 per year) do not have access to a vehicle.

2.2 Characteristics and Correlates of Pedestrian Crashes

Nationally, pedestrian fatalities have been in the decline in the past 20 years from about 7,000 to less than 5,000 annually (see Figure 1). In 2009 there were the fewest pedestrian crashes in decades, while there was a slight uptick in 2010. Fatality rate trends—or fatalities adjusted per number of walking trips or miles traveled by walking—are unavailable due to a lack of systematically collected measures of exposure to walking near traffic. Thus it is unclear whether declines in fatalities can be attributed to lower rates of walking, improvements in safety behaviors or facilities, or a combination of factors.

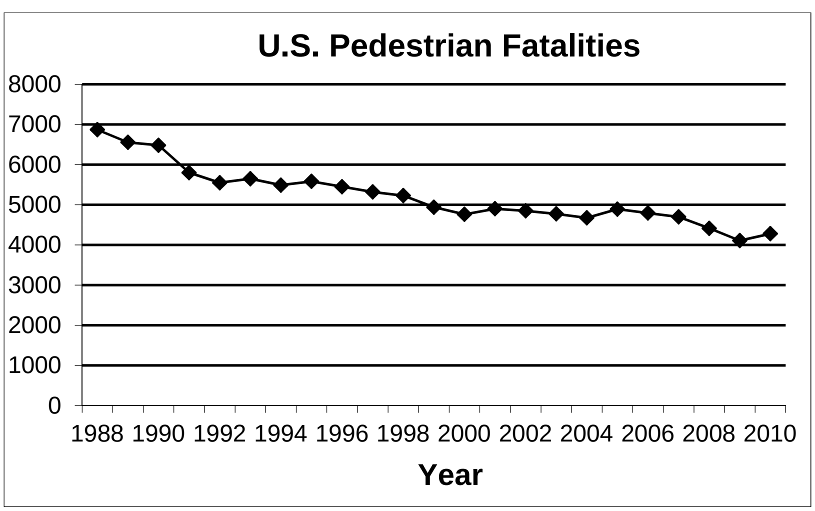


Figure 1. Pedestrian fatalities in the United States from 1988 to 2010 (source: Traffic Safety Facts 2009, Early Edition (NHTSA, 2012b, Table 4) and Traffic Safety Facts 2010 (NHTSA, 2012a))

Children age 15 and younger accounted for 7% of the pedestrian fatalities in 2010 and 23% of all pedestrians injured in traffic crashes (NHTSA, 2012a). In the same year, 19% of those killed were adults 65 and older. Both of these age groups have seen decreases in the proportion of total pedestrian crashes and fatalities in recent years. Among other age groups, crash frequencies have remained relatively the same or have slightly increased, particularly among those 45 to 54 (NHTSA, 2012a). Although pedestrian fatalities involving older adults have declined over the past 10 years, older pedestrians are still more likely to die from their injuries when struck. Pedestrians 75 and older have the highest fatality rate per population of any age group (2.2 per 100,000 population; NHTSA, 2012a). In comparison, pedestrians 25 to 64 years old have a fatality rate of 1.6 per 100,000 population (NHTSA, 2012a). Older adults are also more vulnerable when struck in intersection collisions. Although pedestrians of all ages are more frequently killed at non-intersection locations (75% overall), 35% of adults 65 and older died as a result of collisions at intersections in 2009 compared with 21% for other ages (NHTSA, 2012b, p. 131). Males are also commonly over-represented in pedestrian crashes and fatalities, accounting for 69% of those killed in 2010 (NHTSA, 2012a).

Studies have also examined the location and timing of pedestrian crashes. One study examined more than 5,000 pedestrian crashes that occurred in California, Florida, Maryland, Minnesota, North Carolina, and Utah (Hunter, Stutts, Pein, & Cox, 1996). It was determined that 32% of pedestrian crashes occur at or within 50 feet of an intersection. Of these, 30% involved a turning vehicle; another 22% involved a pedestrian running into the intersection, and 16% involved a driver violation such as running a red light. Older pedestrians are over-represented in collisions with turning vehicles and motorist violations. Another 26% of crashes occur in the middle of a block. These often involve a pedestrian that was obscured from the driver view or vice-versa. Children are often over- represented in crashes at midblock locations. About 7% of crashes involve a pedestrian walking along a roadway where no sidewalk is present. In the majority of these crashes, the pedestrian is struck from behind while walking in the same direction as traffic. Darkness and location in a rural area are common factors in these crashes as well. While many states systematically fail to collect or discard off-road crash records, crashes occurring in these locations may constitute a significant portion of pedestrian-related crashes. In several studies, parking-lot and driveway-related crashes represented up to 15 to 25 percent of all reported pedestrian crashes (Stutts & Hunter, 1999).

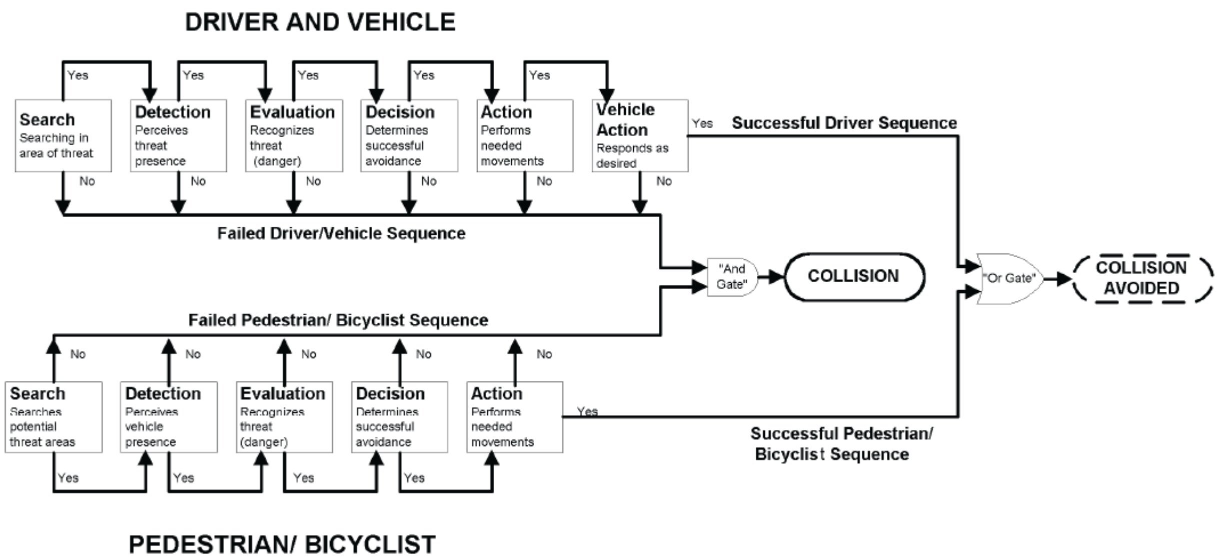
A significant body of research over several decades has established numerous factors associated with pedestrian crashes. Pedestrian and driver pre-crash actions and behaviors (such as distraction, driver speed, and alcohol use), vehicle type and design, pedestrian and vehicle volumes/exposure, and elements of the built environment (including roadway design, presence of pedestrian facilities, and street-crossing facilities) all contribute to pedestrian crashes. Several studies have provided evidence of the role of the transportation environment in pedestrian safety and summarized best practices in engineering and design for pedestrian safety (FHWA, 2011; Redmon, 2011; Retting, 2003).

2.3 Nature of Pedestrian Interventions

In the past two decades, the magnitude of the pedestrian crash problem, coupled with a growing awareness of the health benefits of walking, has given rise to a number of interventions to improve pedestrian safety, some of which are described in Table 1. Most of the existing pedestrian safety interventions were developed by communications contractors or local or state transportation agencies seeking to reduce roadway fatalities. Given their origins and the nature of the funding sources, most interventions have little to no involvement from public health staff and no theoretical underpinnings. Further, due to limited resources and staff capacity, such interventions are rarely formally evaluated using methodologically-rigorous study designs. Part of this dissertation proposes to evaluate a specific pedestrian safety intervention, unique in that it was influenced by several health behavior change models or theories. Following is a brief summary of the theoretical underpinnings of various pedestrian interventions that were considered in the development of the intervention to be evaluated in this dissertation project.

2.3.1 Theoretical Basis of Pedestrian Safety Interventions

Snyder and Knoblauch (1971) developed a behavioral model of pedestrian and/or bicycle crashes, consisting of five key behaviors or functions in a sequence leading to a crash (Figure 2).



Adapted from Snyder and Knoblauch (1971)

Figure 2. Behavioral model of pedestrian-MVC crashes.

The critical behaviors in the sequence leading to (or avoiding) a crash are:

- Search: Both driver and pedestrian/bicyclist scan their environment for potential hazards.
- Detection: Each sees the other.
- Evaluation: Each recognizes the threat of a collision and the need for action to avoid it.
- Decision: Each determines what action to take to avoid a collision.
- Action: Either pedestrian/bicyclist or driver or both successfully perform(s) the appropriate action.
- Vehicle response: A factor for a motor vehicle or bicycle driver is the response of the vehicle to the action taken.

By this model, if either party to a potential crash (either pedestrian or driver) can successfully perform the above sequence of behaviors, a crash will be avoided. That said, failure to avoid a crash is not the same as fault or culpability in a crash, as factors of the built environment or other road users may interfere with the ability of pedestrians or drivers to successfully perform each sequence.

Pedestrian or bicycle safety interventions operating under this model can reduce or prevent crashes in one of several ways:

- By eliminating or reducing human errors, such as by increasing road users' ability to perform these behaviors (in particularly searching and detecting each other) and improving their understanding of legally and socially appropriate actions to take, such as yielding to the other or passing safely, etc.

- By creating a “safety net” whereby one person in the sequence can compensate for the errors of another, such as requiring drivers to stop before passing a car that is yielding to pedestrians, in the event that a pedestrian cannot see/detect the passing car in time to avert a crash
- By changing the built environment so that a potential crash is less likely or is easier to see and avoid.

Several more general models or theories exist regarding human behavior change. These were considered in the context of the pedestrian and driver behaviors described above and had some influence on the intervention design and/or its evaluation measures.

Behavioral scientists consider ecological models to provide the most useful guidance for efforts to change health behaviors, including travel behaviors of pedestrians, bicyclists, and drivers. The literature commonly cites the socio-ecological framework (see Figure 3) to illustrate the complex web of factors that affect behavior (Northridge, 2003; Sallis, Owen, & Fisher, 2008; Sallis et al., 2006). Health behaviors do not occur in a vacuum: individual behaviors are influenced not only by individual characteristics (such as knowledge, attitudes, or perceived risk) but also by interpersonal factors (such as social networks and peer influences), the environment (including roadways, land use, climate, etc.) and broader socio-cultural factors (such as policies, political, economic, and other contexts).These multiple levels of influence on health behavior also interact. The practical implication of the socio-ecological framework is that multi-level interventions are likely to be the most effective in changing health behavior.

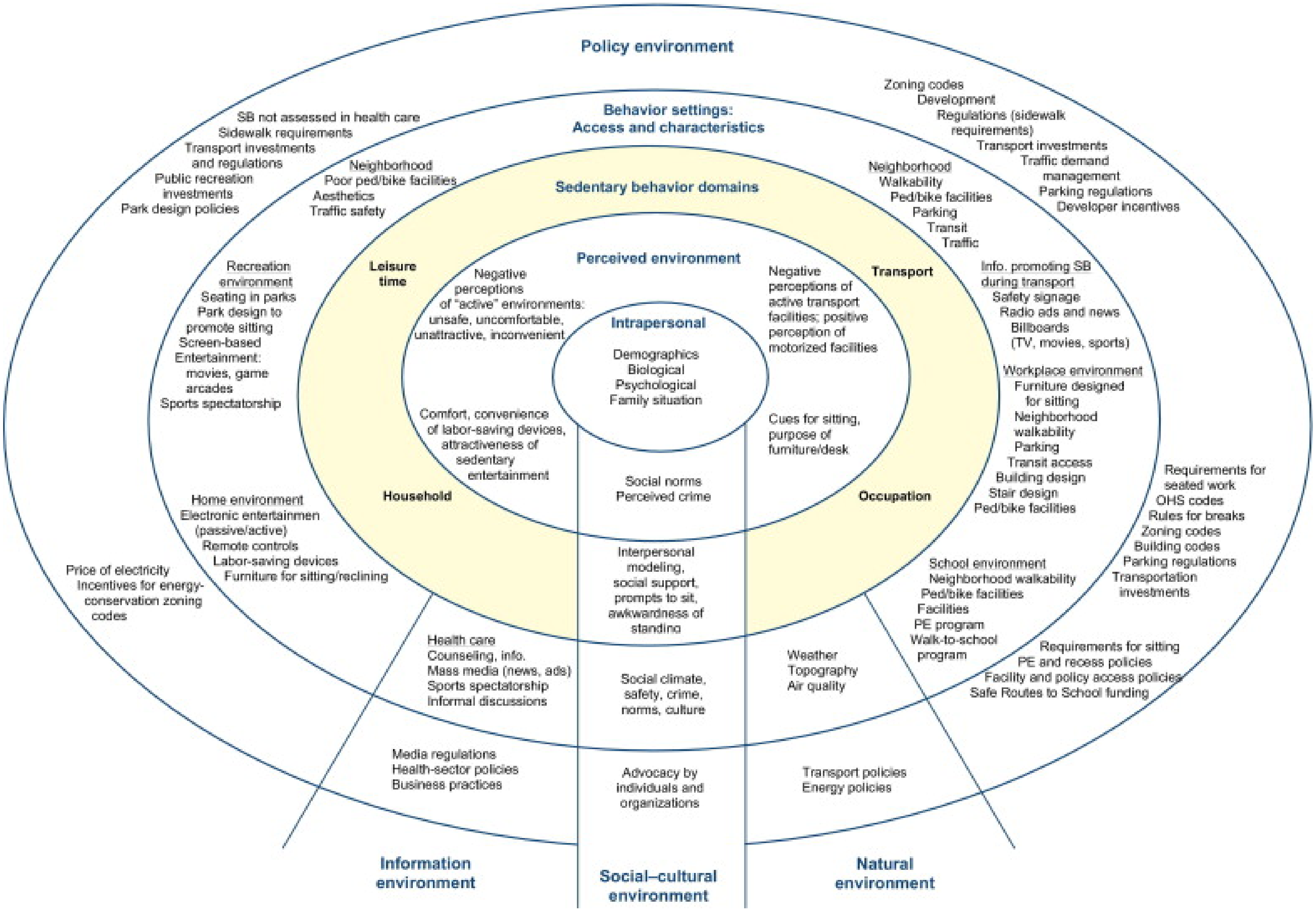
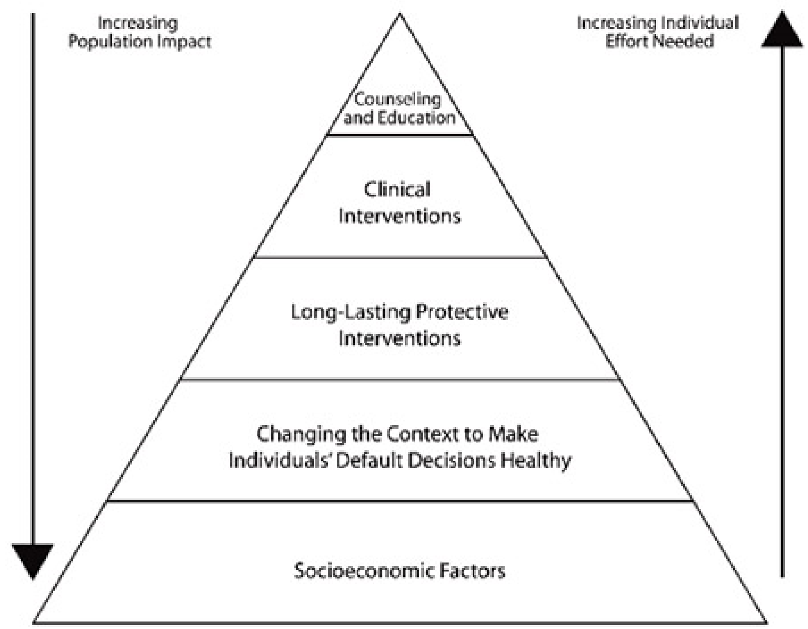


Figure 3. An example socio-ecologic framework: the ecological model of four domains of active living (Sallis et al., 2006).

The Centers for Disease Control and Prevention (CDC) Health Impact Pyramid, shown in Figure 4, uses a similar ecological model (Frieden, 2010). The Health Impact Pyramid shows that interventions have an increasing impact on populations as they reach broader system structures. Whereas educational interventions must be consistently and repeatedly applied to have a tangible impact, changing the context (e.g., through community design, policies, and enforcement) requires less individual effort and has a greater population impact than individual education. The CDC considers such contextual changes to be the most effective public health actions. Implementing these changes can be difficult and time-consuming, but once in place their intended benefits are achieved more broadly and with less effort than individually-oriented efforts.



Individual Education:

- Counseling and public education to avoid drinking and driving
- Encouraging compliance with traffic laws

Changing the Context for Public Health:

- Safer roads and vehicle design
- Designing communities to promote increased physical activity
- Enacting policies that encourage public transit, bicycling, and walking instead of driving
- Enforcing laws mandating helmet use

Figure 4. Health impact pyramid (Frieden, 2010).

Given the complex web of influences illustrated in ecological frameworks, practitioners must recognize that human behaviors and decisions are not easily changed at the individual level.
For pedestrian safety interventions, a policy and physical environment that makes the safe option the default option must be in place to support messages targeted at individuals.

The Stages of Change Theory (also known as the “Transtheoretical model” or “TTT”) describes each stage of the continuum of motivation and readiness for individual behavior change:

1. Pre-contemplation (no intention of change)
2. Contemplation (thinking about taking action)
3. Preparation (planning to take action),
4. Action (change lasting less than six months)
5. Maintenance (change lasting for more than six months), and
6. Termination (change with no threat of relapse)

The goal of pedestrian safety interventions based on the TTT model is to move people to the next stage of change, excluding the termination stage (Prochaska, DiClemente, Velicer, & Rossi, 1993).

The Health Belief Model explains personal behavior change as influenced by the perceived susceptibility and severity of a health risk, the perceived benefits and barriers to taking action, and internal or external "cues to action" that prompt one to take action (Champion & Skinner, 2008). Many existing pedestrian or traffic safety campaigns—whether intentionally or not—build on this model by aiming to educate the public about the magnitude of the problem and the risk and cost of pedestrian and bicycle crashes.

Deterrence Theory is based on the notion that people are more likely to avoid illegal behaviors when they believe that punishment for the behavior is certain, and will be both swift and severe (H.L Ross, 1982). Many traffic safety programs are predicated on this theory. Most recently, a pedestrian safety effort in Gainesville, Florida, has used deterrence theory to influence drivers to yield to pedestrians in crosswalks (Van Houten et al., 2013). Police officer presence around crosswalks was enhanced and bus wraps and high-visibility media messages reiterate the consequence of ticketing if drivers fail to yield. However, it is unknown whether the communication approaches used influenced perceptions of the swiftness, certainty, or severity of the consequence.

The Social Cognitive Theory ("Social Learning" theory) is based on the notion that people learn what behaviors are appropriate and expected by observation of others. Behaviors are learned, in part, by observing others, but also by practicing the behavior and receiving reinforcement to continue the behavior (Bandura, 1986). Under this theory, if some drivers begin to yield to pedestrians at crosswalks, for example, then other drivers could sense that this both appropriate and expected and begin to perform the behavior as well, provided they receive other reinforcements to continue.

The Diffusion of Innovation Model describes the spread of adoption of new behaviors through a population (Rogers, 1995). To appeal to early adopters, efforts to promote a new health behavior would position it as innovative. On the other hand, efforts to appeal to the late-comers would position the behavior as mainstream. Details of how the above theories were considered and incorporated into tangible elements of the pedestrian intervention are provided in Section 2.3.

2.3.2 Prior Studies

As previously stated, while numerous pedestrian safety interventions are known to have been implemented in the United States, there are few quality and/or published reports evaluating their effectiveness. Further, the nature of pedestrian interventions is quite diverse, often resulting in a lack of comparability or generalizability among those interventions that have been adequately evaluated. For the purpose of this study, existing or prior pedestrian interventions have been categorized into the following types: 1) school-based, 2) infrastructure-based, and 3) community-based.

School-based/curriculum interventions typically target school-children and/or care-givers with educational strategies delivered in a school or afterschool care setting. Child-only or school education only pedestrian safety evaluations are abundant (Mulvaney et al., 2006; Rivara et al., 1991; Kendrick et al., 2007; Preusser and Blomberg, 1984; Gresham et al., 2001; Hotz et al., 2004; and Duperrex, 2002). However, these will not be included in this review as the primary recipient of these interventions (children) is very different from the Watch for Me NC primary recipient (adults) and the intervention design is not comprehensive enough to support a generalization of the results to the study at hand.

Infrastructure-based interventions are those that make changes to the built environment to improve conditions for safer pedestrian and motorist movement and interaction. The evaluation of such infrastructure treatments has been heavily covered in other literature (Fitzpatrick et al., 2006; Harkey et al., 2004; Retting, 2003) and crash-based studies are well-documented in the Crash Modification Factors clearinghouse (http://www.cmfclearinghouse.org/) and will therefore not be included here. The remainder of the literature review targets evaluations of community-based, multi-faceted interventions that include both education and enforcement elements targeting a broad population, including adults and possibly children. Most studies focus on evaluating three different types of outcome measurement: knowledge change, behavior change (i.e., stopping at the curb; using crosswalks and signals, driver speed/yielding, etc.), or crash frequency/rate change. While crash-based studies are considered the "gold-standard" among the highway safety field, only two studies evaluating a community-based pedestrian program were identified through this literature search.

The StreetSmart program in Washington, DC is regarded as one of the longest-running pedestrian education and enforcement programs in the US, in operation since 2000. While its intervention approach using enforcement and public outreach has been widely modeled, the intervention has not been scientifically evaluated. Evaluation measures to date have focused on surveys of driver and pedestrian knowledge and awareness of the intervention activities and message. Although the survey results indicate positive changes in these measures, the survey methods have not been published and thus the study and its findings cannot be thoroughly assessed.

Huang and Petritsch (2006) evaluated three separate community-based pedestrian safety interventions occurring in Missoula, MT, Savannah, GA, and Washington, DC; each was tasked with using or adapting pedestrian safety campaign materials provided by the Federal Highway Administration (FHWA). The local partners, timeframe, and intervention activities varied widely, but evaluation measures were consistent across the sites: a survey of pedestrians and drivers to measure awareness of the program and safety messages, and observations of pedestrians and drivers at selected intersection crosswalks. For each community, cross-sectional intercept surveys (targeting between 70 and 400 pedestrians and motorists before and after) were conducted at up to 6 locations. Observations of pedestrian behaviors (compliance with the signal) and conflicts with drivers were conducted at between 200 and 800 signal cycles at up to 8 locations. The study (not formally published) does not describe site selection or characteristics for the observational data collection or survey sampling methods or response rates. Results varied across the three cities, but the nature of the study design limits the applicability of the findings. The study used only two measures in time, had small sample sizes, did not describe any measures to control for potential confounding, and no control locations were used. In addition, poor documentation of the intervention activities, and lack of discussion of the data collection measures and analysis methods prevent any replication of the effort. The authors concluded that additional funding and reliable community champions were needed to ensure the strength of the intervention implementation.

Van Houten and Malenfant (2004) examined driver yielding at 20 crosswalks along two corridors in Miami Beach, FL before, during, and after an intervention involving targeted police enforcement and local publicity. The researchers used a repeated-measures design and compared yielding at eight treated sites to that at 12 untreated sites. They found that driver yielding to pedestrians at treatment sites increased after the intervention; yielding also increased to a lesser extent at the untreated crosswalks in the affected corridors. Increases in yielding were sustained for up to a year following the two-week intensive enforcement efforts with nominal additional enforcement, but effects on crashes and injuries were not reported. The publication includes raw percentages of drivers yielding but provides no details on the analysis methods or discussion of other factors that could have confounded the findings.

Van Houten et al. (2013) performed a more rigorous evaluation of an enforcement-based intervention that was similar in design to their 2004 work. In this instance, they randomized enforcement to 6 of 12 sites and gathered repeated measures of driver and pedestrian behaviors. Time-series regression models were used to examine changes in observed driver and pedestrian behavior at both treated and untreated sites. The study found that driver yielding increased at both treated and untreated sites. The authors suggested that, due to the high-visibility public outreach component of the intervention, the enforcement program effects generalized to crosswalks not targeted for enforcement.

Nee and Hallenbeck (2003) evaluated pedestrian and motorist behavior changes attributed to an intervention involving engineering, enforcement, and public education. A before and four-phase after design was used at two sites, with no control sites. Researchers observed improved pedestrian behaviors (use of refuge island) and driver yielding increased from 0% at baseline to 17-70%. The enforcement component of the program was limited and authors attribute much of the change in behaviors to the significant package of environmental improvements and pedestrian crossing facilities. Similar to Van Houten and Malenfant (2004), data is presented in terms of raw percentages of yielding and it appears that no modeling or work to control for confounders or temporal trends was performed.

Turner et al. (2004) reviewed the literature regarding community-based child pedestrian interventions focusing on studies with behavioral or crash outcomes and a community or historical control group. Only four studies of 314 identified met the inclusion criteria. None utilized any randomization of the intervention or other methods to address potential bias due to confounding factors such as walking trends or other community changes. The studies varied widely in their geographic coverage (including Perth, Australia, Manhattan, NY, and Harstad, Norway), their timeframe (1976-1997), and the intervention measures (traffic calming, safe routes to school, playground improvement, mass media, legislative changes, etc.). However, all studies saw reductions in childhood injuries (ranging from 12 to 54%) or improvement in traffic conditions or driver behaviors. The authors concluded that while there is a paucity of well-designed research studies, the available research supports the hypothesis that community-based interventions can effectively reduce the incidence of (child) pedestrian crashes, depending on the complexity of the intervention strategies used.

In a study by Datta, Savolainen, and Gates (2011), law enforcement officials in Detroit, MI implemented two pedestrian-oriented enforcement campaigns at Wayne State University aiming to educate campus pedestrians on proper use of crosswalks and signal-abidance through the issuance of warnings. Researchers used two sample z-test of proportions to determine the statistical significance of any changes in observed child behaviors or pretest/ post-test knowledge. For the adult pedestrians, two sample tests of proportions to examine changes in various behaviors before, during, and after enforcement were conducted, using Bonferroni Multiple Comparison Correction to account for multiple hypothesis testing on the same dataset. The study saw pedestrian violations (walking outside the crosswalk or against the signal) reduced 17 to 27% immediately after the campaign, with sustained reductions of 8 to 10% several weeks after active enforcement ceased. Study authors noted that pedestrian compliance was also heavily associated with the presence, quality, and location of pedestrian facilities (including pedestrian signals, bus stops, crosswalks, and convenient crossing opportunities), many of which were improved during the study period as part of the intervention.

Zegeer, et al. (2008) produced one of the most rigorous, crash-based evaluations of a comprehensive pedestrian safety intervention to date, utilizing a multivariate autoregressive integrated moving average (ARIMA) time-series analysis, along with nonparametric U tests, to test changes in pedestrian crash rates over time. Three separate comparison groups were used (the adjacent county, a six-county region, and statewide) to help remove the effects of pre-existing trends or temporal confounders. Overall, there was an 8.5% to 13.3% reduction in pedestrian crash rates during and following the program implementation compared to the untreated groups. A sub-analysis of crash trends in specific "zones" of Miami Beach revealed that the zones with the most intensive intervention activities (Liberty City and South Beach) were the ones with the greatest reduction in crashes, indicating the potential for a dose-response effect.

Table 1 summarizes the literature regarding evaluations of community based pedestrian safety programs that have been evaluated using knowledge, behavioral, and/or crash based measures. Interventions addressing specific sub-groups (such as children) are not listed.

Table 1. Summary of evaluations of community-based pedestrian interventions.

Study	Location	Intervention Timeframe	Intervention Measures	Study Design	Outcome Measures and Analysis Method	Results
StreetSmart (2012)	Washington, DC	2000-Present; Evaluation covers only 2011-2012 program	• Radio ads • Outdoor ads • TV and digital media • Kickoff event • Law enforcement	Surveys conducted before and after intervention; no control groups	Knowledge, awareness, and attitudes among drivers and pedestrians; no methods documented	10% increase (from 32 to 42%) in awareness of enforcement efforts; 7% increase in awareness of the campaign
Huang and Petritsch (2006)	Missoula, MT	2004-2005	• Radio ads • Outdoor ads • TV and digital media • Law enforcement	Before and after intervention observation of behaviors and survey; no control groups/sites	Chi-square test to measure differences in knowledge, awareness, and driver and pedestrian behaviors (use of signal and conflicts at crossings)	Pedestrians and motorists reported more awareness/recall of the program in the after period; few conflicts were observed and pedestrian behaviors (looking before crossing) showed modest improvements
Huang and Petritsch (2006)	Savannah, GA	Intermittent activity between 2005-2006	• TV news features • Crosswalk awareness actions • Walk to School Day	Before and after intervention observation of behaviors and survey; no control groups/sites	Chi-square test to measure differences in knowledge, awareness, and driver and pedestrian behaviors (use of signal and conflicts at crossings)	No significant changes were detected in pedestrian or driver awareness/recall of the program; no improvements in behaviors were observed; intensity of the intervention was extremely low
Huang and Petritsch (2006)	Washington, DC	2003	• Radio ads • Transit ads • TV and print coverage • Kickoff event • Law enforcement	Before and after intervention observation of behaviors and survey; no control groups/sites	Chi-square test to measure differences in knowledge, awareness, and driver and pedestrian behaviors (use of signal and conflicts at crossings)	Pedestrian awareness/recall of the program actually decreased significantly in the after-period; driver recall did not significantly change; pedestrian behavior (start crossing during WALK phase) saw modest increase but changes in driver behavior were not detected
Nee and Hallenbeck (2003)	Shoreline, WA	1999-2003	• Environmental changes • Law enforcement • Public information campaign	Before and 4-phase after observation of behaviors at two sites; no control sites	Chi-square test to measure differences in behaviors (pedestrian crossing behaviors and driver yielding) before and after intervention	Improved pedestrian behaviors (use of refuge island) and driver yielding from 0% to 17-70%, likely due to the significant package of environmental improvements and pedestrian crossing facilities. Driver compliance increased only on one leg of one intersection after the enforcement portion of the intervention; enforcement intensity was limited.
Van Houten and Malenfant (2004)	Miami Beach, FL	2-week intervention and 1-year maintenance period (year not known)	• Press releases and earned media (TV and print) • Law enforcement	Repeated measure of driver behaviors before, during, and after intervention; 8 treated and 12 non-treated sites	Analysis method not described; raw percentages of driver yielding at each site and measurement wave were provided	Driver yielding went from 3.3% and 18.2% at baseline to 27% and 33.1% at the two treated corridors, respectively. Yielding at the untreated sites rose from 20.5% to 32.1%, which authors attribute to a spill-over effect of the high-visibility education component.

Study	Location	Intervention Timeframe	Intervention Measures	Study Design	Outcome Measures and Analysis Method	Results
Van Houten et al. (2013)	Gainesville, FL	2010-2011	• High-visibility law enforcement • Media coverage • Paid media • Signage • Environmental changes	Randomized enforcement to 6 of 12 sites; repeated measures of driver and pedestrian behaviors	Time-series regression models of changes in observed driver and pedestrian behavior at 12 sites	Yielding for staged crossings rose from 31.5% to 62%, and yielding for natural crossings rose from 45.4% to 82.7%. Program effects generalized to crosswalks not targeted for enforcement and were inversely proportional to the distance from the treated sites.
Datta et al. (2010)	Detroit, MI	2008-2009	• Environmental changes • Development of action plan • Law enforcement • Education and public outreach	Repeated measure of child pedestrian and adult pedestrian behaviors before, during, and after intervention; pre/post-test of child pedestrian knowledge; no control groups used	Two sample z-test of proportions to determine the statistical significance of any changes in observed child behaviors or pretest/ post-test knowledge; two sample tests of proportions to examine changes in pedestrian behavior before, during, and after enforcement, using Bonferroni Multiple Comparison Correction	Child pedestrian violation rate decreased from 34.79% to 30.35%; increases in the correct response were observed at all schools; pedestrian violations (walking outside the crosswalk or against the signal) reduced from 17 to 27% immediately after the campaign, with sustained reductions of 8 to 10% several weeks after active enforcement ceased
Zegeer et al. (2008)	Miami-Dade County, FL	1999-2003	• 16 specific education, enforcement, and engineering countermeasures targeting children, adults, and seniors	Before-after evaluation of pedestrian crash rates, using three comparison groups	Multivariate intervention ARIMA time-series analysis, along with nonparametric U tests were used to test changes in pedestrian crash rates over time	County-wide crash rates were reduced from 8.5% to 13.3%, depending on the comparison group used to adjust the model

3. SPECIFIC AIMS

The purpose of this dissertation is to 1) contribute to the literature on the descriptive epidemiology of pedestrian-motor vehicle crashes, and 2) to perform a rigorous scientific evaluation of a safety intervention to reduce pedestrian crashes and injuries through education, enforcement, and officer training and capacity-building. The dissertation will address two major aims, each with several sub-aims:

3.1 Aim 1: Characterize the incidence, spatial distribution, and correlates of pedestrian crashes and fatalities in NC.

Aim 1.1: Describe the epidemiology of police-reported pedestrian crashes and fatalities in NC and identify community level socio-economic correlates of crashes.

Approach: Describe trends in pedestrian crashes and fatalities by seasonality, geography, injury severity, individual characteristics, and population factors. Pedestrian crashes for this and all aims are defined as collisions between a motor vehicle and one or more pedestrians on a public roadway, resulting in potential or confirmed injury to the pedestrian and/or property damage. Analyze crashes at the crash event level, using the characteristics of the first pedestrian harmed in each crash event. Compute crash and fatality frequencies and incidence rates for pedestrian crash events per 1,000 person-years using 2010-2011 crash data and residential denominators. Classify crashes by pre-crash action (i.e., crash type) and injury severity. Combine police-reported geo-coded crash data with block-group level census information to estimate the association between various socio-economic characteristics of the neighborhoods in which the crash occurred (including household income, vehicle ownership, education status, and employment status) and pedestrian crash frequencies and incidence rates.

Aim 1.2: Describe the epidemiology of Emergency Department attended pedestrian crashes in NC.

Approach: Analyze crashes at the patient level, using the characteristics of each pedestrian involved in any crash event. Calculate pedestrian crash frequencies and incidence rates per 1,000 person-years. Describe the distribution of crash victim age, county, arrival date and time, chief complaint (primary reason for ED visit), codes detailing injury diagnosis and external cause, and disposition.

3.1.1 Aim 1 Hypotheses

H1.1: Pedestrian crash and fatality frequencies and incidence rates will vary by season and geography and are not uniformly distributed across population sub-groups. Census block groups with higher proportions of non-White and low-income groups will experience more pedestrian crashes. Pedestrian crash frequencies and rates will be inversely associated with socio-economic levels (meaning that crash counts and rates will be higher in areas with lower socio-economic values).

H1.2: ED patient pedestrian crash frequencies, rates, and distribution (such as age, county, and arrival date and time) are consistent with those of police-reported crash data. Injury type, code, and disposition will reflect more severe injuries than are represented in the police-reported crash data due to the self-selection of those presenting at EDs.

3.1.2 Aim 1 Rationale

In recent years, there have been significant changes in population demographics and migration trends, as well as statewide policies (such as a Complete Streets policy enacted in 2009 requiring the uniform consideration of pedestrians and other road users in the design of new roadways) that have affected the nature of pedestrian crashes. However, the descriptive epidemiology of pedestrian crashes in North Carolina is not well documented for years since 2009. Past reports (UNC, 2011) on pedestrian crash trends in North Carolina have not utilized geo-coded crash data (made available for years 2010 and 2011 in April of 2013), nor have they utilized available census data or emergency department data to compare trends or develop hypotheses regarding the nature of socio-ecological crash correlates. Notably, this study makes use of data sources that are unique in that North Carolina is one of the few states in the nation to have statewide ED data as well as a statewide database of detailed and geo-coded pedestrian crash data. As mentioned in the hypothesis, it is anticipated that more severe pedestrian crash cases will present at the emergency rooms. Utilizing ED data will thus provide a way to explore the higher-severity cases that can't be seen using DMV crash records alone and will offer a more comprehensive description of the nature of pedestrian crashes.

3.2 Aim 2: Quantify the effects of a pedestrian safety intervention, Watch for Me NC, focused on modifying driver and pedestrian behavior.

Aim 2.1: Describe the Watch for Me NC intervention and implementation in Year 1 (2012) and Year 2 (2013).

Approach: Describe the intervention strategies, assess program delivery through measures obtained from intervention implementation records, and identify strengths and challenges in implementing behavioral interventions to promote pedestrian safety.

Aim 2.2: Assess the effects of the Watch for Me NC intervention on law enforcement officers participating in the capacity-building component of the program, which involved participation in a two-day training course in 2013.

Approach: Quantify changes in Triangle-area law enforcement officer self-reported knowledge, attitudes, sense of capacity, and stages of change (or readiness) to enforce pedestrian safety laws. Assess changes immediately before and immediately after the two-day training course.

Aim 2.3: Estimate the effects of the Watch for Me NC law enforcement program on driver behavior.

Approach: Calculate the average driver yielding rates at treatment and comparison sites before and after the intervention using field observation data.

Aim 2.4: Estimate the effects of the Watch for Me NC program on crash incidence.

Approach: Estimate the association between the Watch for Me NC intervention and police-reported pedestrian crash incidence rate per 1,000 population in the Triangle area in comparison to other non-intervention comparison locations.

3.2.1 Aim 2 Hypotheses

H2.1: Various intervention strategies, including public outreach and engagement as well as high-visibility law enforcement, will be implemented and program activities will not be evenly distributed across communities. Communities with higher staff to population ratios and prior commitment to pedestrian initiatives will have greater likelihood of implementing key intervention components, including communication and enforcement, as measured by a range of program implementation records.

H2.2: Officer knowledge, attitudes, and sense of capacity will increase as a result of the training; officers will have an increasingly positive attitude toward conducting pedestrian enforcement and will advance in their stage of change/level of readiness.

H2.3: Driver yielding rates will be higher at the treated sites and will increase over time, in comparison to the baseline and untreated sites. A dose-response effect will be observed at sites that receive more enforcement treatments over time, as more enforcement activity will directly reach a greater population of area drivers.

H2.4: Pedestrian crash rates per capita will decrease throughout the duration of the pedestrian safety intervention, and crashes will decrease at a faster rate in comparison to non-treated groups.

3.2.2 Aim 2 Rationale

No studies have evaluated a pedestrian safety intervention using such a comprehensive set of measures, including intervention implementation records, self-report, observational behavior, and crash-based measures. New and better quality research is needed to examine the effectiveness of theory-driven interventions that include both educational and enforcement components. Such research can help predict the likely effectiveness of pedestrian interventions on crashes and behavioral outcomes, and ultimately, this research will be part of efforts to assist localities in designing, implementing, and evaluating such programs.

4. RESEARCH DESIGN AND METHODS

This section describes the intervention of interest as well as the methods, data resources, and analytical approach to accomplish each of the Aims. Section 4.1 details the design of the intervention to be examined in Aim 2. Sections 4.2 and 4.3 detail the data sources and data collection methods, and proposed statistical analysis methods, respectively.

4.1 Intervention Design

The intervention of interest for Aim 2 is called Watch for Me NC. Watch for Me NC is a collaborative, community-led effort conducted in partnership with state and local transportation agencies and police departments. Since October 2011, municipalities in Orange, Durham, and Wake Counties have been working with UNC-HSRC staff to develop a comprehensive set of safety initiatives to target specific safety concerns identified through crash data analysis, plan review, and community input. Crash data, intervention details, and all media and messaging materials can be found at the program web site, www.watchformeNC.org.

The candidate has been closely involved in the development and implementation of the intervention and leads the project through her position as a Senior Research Associate at UNC's Highway Safety Research Center. The intervention was designed based on several principles and theories articulated in Section 2.2.1. The intervention is multi-level and deterrence-based, targets readiness and measures stage of change, and leverages social learning and diffusion of innovation. Each of these aspects of the intervention is discussed below.

Multi-level: The intervention includes education (both direct and passive outreach), enforcement of laws, partnership development among municipal and police staff, and policy-change (such as provision of funding for routine education and enforcement support), which are coupled with on-going environmental improvements that are taking place independently of the intervention itself. This approach embodies a socio-ecological framework aiming at broader system structures that affect individual and group behaviors.

Health-risk driven: Interventions that target specific and defined behaviors and health risks are considered superior to programs that advocate that road users "be safe" or "street smart" or provide other vague messages. The Watch for Me NC program developed a series of specific messages targeted at behaviors identified as factors associated with common crashes based on an evaluation of five years of crash data in the Triangle. For example, a large portion of crashes occurred at intersections and involved drivers making turning maneuvers. Messages to pedestrians and to drivers emphasized the risk of crashes at intersections and advised them to scan in all directions for other road users before making their way through an intersection. Efforts to increase road user scanning and detection of other modes is consistent with the Snyder and Knoblauch (1971) behavioral model of pedestrian crashes.

Deterrence-based: The deterrence theory was considered in the development of intervention messages, some of which emphasized the legal consequence of failure to yield to pedestrians. Interviews with multiple press outlets emphasized the extensive enforcement outreach and the potential for tickets and warnings to those failing to obey the laws. Officers were also instructed to stress their city-wide presence and the likelihood of stopping (and punishing) errant drivers and pedestrians. They were provided with template press releases and other materials to help them highlight their enforcement efforts and summarize citation data.

Targets readiness and measures stage of change: With the law enforcement training in particular, the intervention aims to move people to the next stage of change, so that officers in the pre-contemplation or contemplation stage move to prepare to take action or maintain action to support pedestrian safety through advanced law enforcement techniques. Measures of stages of change were built into the questionnaire answered by training participants, described later.

Leverages social learning and diffusion of innovation: Programs with elements that seek to make desired behaviors normative and do not reinforce undesired behaviors have been shown to be effective. Based on driver yielding data collected from July 2012 to March 2013 at 12 high-crash sites in Raleigh and Durham, yielding to pedestrians in marked crosswalks is not yet a normative behavior. On average, drivers yielded to pedestrians approximately 20% of the time. It is anticipated that as yielding (and other safe behaviors) improve, more normative elements can be used and social learning principles can help diffuse the behaviors to other road users as they begin to perceive the behaviors as the norm.

In addition, it is worth noting that the intervention development was largely partnership-driven from the very start. This had some disadvantages in that the intervention design often involved group compromises, local politics, funding limitations, and non-scientific decision-making, leading it away from evidence-based best practice. But the advantages likely outweighed the disadvantages, in that a partner-driven approach led to strong community buy-in and increased capacity to implement the intervention on a large, regional scale needed to saturate the Triangle population.

4.2 Data Sources and Collection Methods

The data sources to be used for Aim 1 (descriptive epidemiology of pedestrian crashes in NC) include police reported pedestrian-motor vehicle crash reports, emergency department data on pedestrian-related events, and Census data relating to population characteristics in NC.

The data sources to be used for Aim 2 (evaluate a pedestrian safety intervention focused on changing pedestrian and driver behavior) include law enforcement program implementation records, questionnaires to assess the effects of training for law enforcement officers, observations of pedestrian and driver behavior at selected locations, and pedestrian-motor vehicle crash reports. Substantial data has already been collected and is housed at HSRC; additional behavioral observations and questionnaire data will be collected in the next six months. Table 2 provides a summary of data sources to be used and details of the data and collection methods follow.

Table 2. Summary of data sources.

Aim	Outcome Measures	Data Sources
1.1 (DMV and Census)	County-level and block-group level crash frequencies and incidence rates per 1,000 population	• 2010 and 2011statewide police-reported crash data housed at UNC-HSRC • Block-group level Census data
1.2 (ED)	County-level patient case frequencies and incidence rates per 1,000 population	2010-2011 statewide Emergency Department from NCDetect.org
2.1 (Implementation)	Implementation records from enforcement and education activities (see Table 6)	Intervention partners and Google Analytics
2.2 (Self-report)	Self-reported law enforcement officer knowledge/attitude/ capacity and stage of change	Self-administered questionnaire completed by 55 officers in July/August 2013
2.3 (Observations)	Observed measures of driver behavior at marked crosswalks	Field data collected by HSRC staff at 12 sites (both treated and untreated) in Year 1 and 16 sites in Year 2
2.4 (Crash)	DMV-reported pedestrian crash incidence rates per 1,000 population.	Police reported crash data housed at UNC-HSRC.

4.2.1 Police Reported Crash Data

Police-reported pedestrian crash data will be utilized in Aims 1.1 and 2.4. Police-reported crash data are housed at HSRC through a standing contract with NCDOT to crash-type, geo-code, and maintain the data on an HSRC-hosted website, the North Carolina Pedestrian and Bicycle Crash Data Tool: http://www.pedbikeinfo.org/pbcat/index.cfm.

Crash data originates from the NC Division of Motor Vehicles (DMV) Crash Report Form DMV-349, which is completed by law enforcement officers to report MVCs in NC. For a crash to be reportable, it must meet at least one of the following criteria (DMV, 2013):

1. The crash resulted in a fatality, or
2. The crash resulted in a non-fatal personal injury, or
3. The crash resulted in total property damage amounting to $1,000.00 or more, or
4. The crash resulted in property damage of any amount to a vehicle seized, or
5. The vehicle has been seized and is subject to forfeiture under G. S. 20-28.2.

Additionally, reportable MVCs "must occur on a traffic-way (any land way open to the public as a matter of right or custom for moving persons or property from one place to another) or occur after the motor vehicle runs off the roadway but before events are stabilized" (DMV, 2013).

Once received by HSRC, DMV crash reports are individually processed and closely examined, particularly the investigating officer's sketch and narrative description and information regarding the specific location of the crash. This information is used to first confirm that the event was correctly coded and does involve a pedestrian hit by a motor vehicle. Then, based on the crash narrative and other form information, a specific crash type is developed using Pedestrian Bicycle Crash Analysis Tool (PBCAT) and added to the database (Harkey et al., 2006). Finally, the pedestrian crashes are geocoded using Google Earth to identify specific latitude and longitude coordinates, exported as KML files, formatted using Microsoft Excel, and then joined with PBCAT and Crash Variable data. For Aim 1.1, geo-coded data will be assigned and spatially joined to Census block-group attributes; crashes occurring on a boundary line between two block groups will be assigned equally to both groups.

Although occasionally more than one pedestrian is involved in the same crash, the database includes only one record per crash and includes data on only the first pedestrian struck in the crash. Thus, this dataset may under-represent the total number of people affected by crashes, though it accurately reports the total number of pedestrian crashes reported to the police. Note also that past studies have estimated that police-reported crashes represent only about 56% of pedestrian incidents that occur (Stutts and Hunter, 1999). These non-captured incidents include falls, crashes not involving motor vehicles, or crashes involving motor vehicles that do not meet the DMV criteria above or occur on private property.

Currently, crash-typed and geo-coded data are only available Statewide for calendar years 2010 and 2011. Pedestrian crash data from 2007 to 2010 were crash typed and geo-coded for the City of Raleigh and City of Durham for use in the Watch for Me NC effort and are available. Relevant variables from the available data are provided in Table 3. These variables are considered to be the most accurate and reliable among the variables available. See Appendix A for a complete list of variables available through DMV-reported crash data.

Within the database, pedestrian injury is coded using the KABCO scale, which is a measure of the injury level of the victim at the crash scene based on police officer judgment when investigating the crash. With this scale, K = fatality, A = incapacitating injury, B = non-incapacitating injury, C = possible injury, and O = property damage only. The candidate will analyze K-type (fatal) crashes separately from non-fatal crashes. K-type crash records are also submitted to the national Fatality Analysis Reporting System (FARS) database, which is commonly used to analyze pedestrian fatalities (NHTSA, 2011). Because the state DMV data is consistent with the elements contained in FARS but is more readily available (FARS typically has a 2-year lag from the calendar year in which the crash occurs), the FARS fatality dataset is not considered useful for this effort.

Table 3. Key analysis variables from DMV crash data.

Domain	Variable(s) Available
Crash Location	• County • City • Latitude/Longitude • Crash location (intersection, non-intersection) • Locality (urban, rural)
Driver Information	• Age • Sex • Race • Vehicle type
Pedestrian Information	• Age • Sex • Race
Roadway Characteristics	• Traffic control • Speed limit
Temporal/Seasonal Characteristics	• Date of crash, including day of week, month, and year • Time of crash • Light conditions
Crash Characteristics	• Pedestrian injury severity (KABCO coded) • Crash type (from PBCAT)

4.2.2 Census Data

For use in Aim 1.1, Census data from the American Community Survey (ACS) three- year estimate summary file will be obtained at the block-group (BG) level. Block groups, the lowest level of geography published by ACS, are statistical divisions of census tracts and contain between 600 to 3,000 people, or 240 to 1,200 housing units. They are appropriate for this analysis in that they represent small, relatively homogenous populations and are designed to have stable boundaries that do not cross county lines (ACS, 2012; Kravetz and Noland, 2012). In the event that crash rates are unstable at the block-group level (i.e., a large percentage of the rates calculated have very small numerators), the data will be aggregated at the census tract level rather than the block group level. Census tracts represent slightly larger geographies (up to 4,000 housing units) but are still considered to represent relatively homogeneous areas and have been used in several other studies focusing on environmental justice issues (Wier et al., 2009; Morency et al., 2012; Cottrill et al., 2010; Chakravarthy et al., 2012).

Table 4 provides a list of the key analysis variables that will be used in the analysis. Variables were selected a priori based on a conceptual model (Figure 4) of hypothesized associations between variables and the outcome of interest (pedestrian crashes). This conceptual model was informed by several studies (Chakravarthy et al., 2012; Chen et al., 2011; Cubbin and Smith, 2002; Kravetz and Noland, 2012; White et al., 2000; Loukaitou-Sideris et al., 2007; Wier et al., 2009; Campos-Outcalt et al., 2002; Barton and Schwebel, 2007; Laflamme and Diderichsen, 2000) that indicate that various factors may contribute to an association between socio-economic status and higher crash frequencies or rates.

Table 4. Key analysis block-group level socio-economic variables from 2010 US Census.

Domain	Variable(s) Available
Population composition	• Total Population (count estimate) • Residential population density per square mile • % of Households with children under 18 years of age • % of population aged 18 to 21 • % of population aged 70 or more • % males • Living arrangement (% of households that are single-parent families)
Race/Ethnicity	• % White Alone Or In Combination With One Or More Other Races • % Black Or African American Alone Or In Combination With One Or More Other Races • % Hispanic Or Latino Origin • % of population that is native-born • % of population that is immigrant
Education	• % of population with Bachelor's Degree For First Major For The Population 25 Years And Over • % of population with High school degree • % of population with less than high school degree
Employment	• % unemployed
Income	• Median Household Income In The Past 12 Months (In 2011 Inflation-Adjusted Dollars); OR percentage of population with income less than 185% of Federal Poverty Level (used for WIC eligibility) • % of Owner Occupied Housing Units
Vehicle Ownership and Travel Mode	• % of occupied housing units with no vehicle available • Aggregate Number Of Vehicles (Car, Truck, Or Van) Used In Commuting • Means Of Transportation To Work

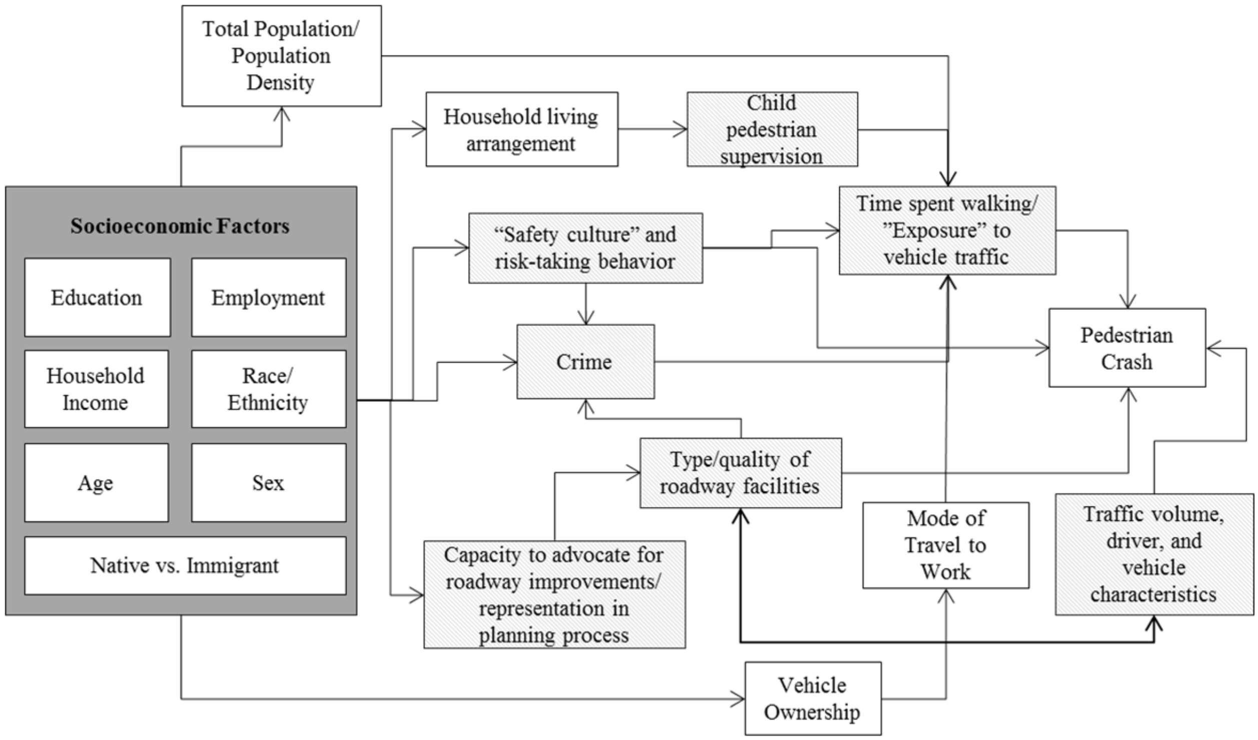


Figure 4. Conceptual model of block-group level socio-economic variables (shaded boxes represent variables not directly measured in this study).

4.2.3 Emergency Room Data

Aim 1.2 will utilize Emergency Room data. For this Aim, 2010-2011 statewide Emergency Department data will be obtained from NCDetect.org. NC DETECT is North Carolina's statewide syndromic surveillance system, and is considered to be one of the most comprehensive and mature near real-time statewide ED databases in the US (Hakenewerth, et al., 2009). The relevant data fields available through the standard Data Use Agreement are listed in Table 5. See Appendix B for a complete list of variables available through the NC Detect Emergency Department database.

NC DETECT data are collected by the North Carolina Hospital Emergency Surveillance System (NCHESS). Staff at the Carolina Center for Health Informatics in the UNC Department of Emergency Medicine (CCHI) review and monitor the quality of the data and develop and manage the NC DETECT database. Inclusion criteria for case reporting include:

- Patients treated in the participant ED regardless of their disposition;
- Patients triaged who then leave AMA or without being seen; and
- Patients treated in the ED and then admitted to the hospital.

NC DETECT was developed in 2004 and by 2007, 80% of hospitals were reporting cases to NC DETECT (Hakenewerth, et al., 2009). As of May 2013, there are 120/122 (99%) of hospitals submitting production-level data daily to NC DETECT (http://ncdetect.org/hospitalstatus.html).

The candidate will isolate International Classification of Diseases, 9th Revision (ICD-9-CM) E-codes (identifying the external cause of injury) pertaining to pedestrian-involved motor vehicle traffic accidents, using the E-codes 810 through 819 with a fourth digit of "7" (pedestrian). While E-coding data is not mandated for NC hospitals, E-codes are available for more than 90% of the data. Though the quality of E-coding varies between hospitals, the overall quality and accuracy of E-coding is considered to be very high.

Table 5. Key analysis variables from ED data.

Domain	Variable(s) Available
Patient Location	• City of residence • County of residence
Patient Information	• Age • Sex
Injury Characteristics	• Chief complaint (reason for seeking care) • Injury code (ICD-9-CM E-code(s)) • Disposition (discharged, admitted, transferred, died, etc.) • Diagnosis code (Up to 11 ICD-9-CM Final Diagnosis Codes)
Temporal/Seasonal Characteristics	• Arrival date and time

4.2.4 Intervention Program Implementation Measures

Aim 2.1 will require the use of program implementation records regarding the implementation of the Watch for Me NC intervention. Records of paid media, earned media, website usage, law enforcement activities, and community engagement activities will be used as measures of the intensity of the education and enforcement elements of the intervention. Collecting program implementation measures will consist of keeping track of all relevant project activities, amount of personnel time, expenditures, and resulting products and materials produced. Appropriate forms and web-based surveys (e.g., tracking sheets for enforcement operations and community engagement activities conducted by partners) will be developed in coordination with partnering agencies. Depending on the intervention element and data source, data collection will be timed to ensure that consistent, high-quality, and reliable data are obtained from partner agencies. See Table 6 for a summary of the program implementation variables available.

Table 6. Key analysis Watch for Me NC program implementation measures/variables.

Domain	Variable(s) Available
Paid Media	• Number of print materials produced and disseminated by NCDOT and duration of exposure time • Total cost of all printed materials and print and radio ad space purchased and cost/capita reached • Number of times PSAs were aired, radio station sources, and estimated number of impressions
Earned Media	• Press release dates • Media coverage source and publication date • Media coverage type, length, and slant • Number of impressions (e.g., media circulation) per media coverage • Ad equivalency (value of earned media) per media coverage
Website Usage	• Website visits • Unique website visitors • Page views • % new vs. returning visitors • Visit frequency and duration
Law Enforcement Activities	• Count of safety operations run by agency • Count and type of warnings and citations administered per operation • Count of enforcement officer hours spent per operation, by agency • Count of safety materials disseminated, by agency

Domain	Variable(s) Available
Community Engagement Activities	• List of partner agencies • Brief description of community engagement strategies used by partner agencies, including type of event, population reached, frequency, staff involvement, etc.

NCDOT and their media purchasing contractor, MSA Marketing, Inc., will provide all information regarding paid media contracting and printing services used from May 2012-January 2014. In terms of earned media (meaning TV, radio, and print news coverage that was not purchased), the Watch for Me NC project team began tracking news articles in May 2012, and has routinely searched Lexis-Nexis archives and GoogleNews Alerts from the period of May 2012 to January 2014.

Data for the Watch for Me NC website usage during the relevant time period will be extracted from Google Analytics. Due to an error in the plugin compatibility with the website, data from 11/17/12 to 1/10/13 is not available. Regarding community engagement activities, in Year 1 four partner agencies provided summaries of activities in monthly meetings, but no formal data collection form was used. For Year 2, data on community engagement will be requested from 18 community partners on a monthly basis.

Law enforcement data will be gathered through direct contact with partnering law enforcement agency staff. In Year 1, eight agencies were contacted bi-weekly with requests for enforcement data. In year 2, 18 agencies will be contacted bi-weekly from September to January with requests for enforcement data. See Appendix C for the program implementation data collection forms sent to police for Year 1 and Year 2. See Appendix C for the program implementation data collection form sent to partner agencies.

4.2.5 Self-Report Data

Aim 2.2 utilizes self-report data collected through a self-administered questionnaire. The questionnaire was designed to measure six key constructs, including: 1) officer knowledge of pedestrian safety issues 2) attitudes regarding the role of law enforcement to promote pedestrian safety, 3) Resources/capacity to implement the Watch for Me NC intervention, 4) Self/unit efficacy, 5) Response efficacy, and 6) Stage of change (see Table 7). Additionally, the questionnaire collected demographic information regarding the police officers. Fundamental to the effectiveness of the Watch for Me NC intervention is the buy-in of the police officers responsible for implementing the enforcement operations to the full extent possible. A common premise, supported by the stages of change theory and other behavioral models discussed earlier, is that officers who are familiar with the law and who have the resources/capacity to enforce the law, coupled with an attitude and sense of efficacy that supports conducting such activities, will be more able to successfully implement the enforcement elements of the program and contribute to the intensity of the intervention.

Fifty five law enforcement officers enrolled in the Watch for Me NC 2-day training course and were provided the questionnaire before and after the course was delivered in July and August 2013. The course covered common pedestrian crashes and causes, NC laws relating to motorist and pedestrian behaviors, and effective practices for law enforcement to reinforce safe behaviors and implement tactical operations aimed at improving compliance with laws, including yielding to pedestrians in crosswalks. All 55 officers completed both the before and after forms, for a 100% response rate. Before and after surveys were linked and data were later matched using an ID code.

See Appendix D for the questionnaire used in Year 2. A questionnaire was provided to officers attending a one-day course in August 2012, but the data set was smaller, many of the instrument measures have since been revised, and data were not individually matched, so this analysis will rely solely on the Year 2 data collected.

Table 7. Summary of questionnaire constructs and items to measure self-reported changes.

Construct	Item/Question #	Format
Knowledge	1. What should a motorist do when approaching a person stepping off a curb at an uncontrolled intersection?	Multiple choice
Knowledge	2. When is it legal for a pedestrian to cross a street mid-block?	Multiple choice
Knowledge	3. Which of the following statements is NOT a North Carolina Law?	Multiple choice
Stage of change	4. What best describes the current pedestrian safety operation plans in your department/unit?	Multiple choice
Knowledge	5. I am familiar with the laws protecting pedestrian safety in North Carolina.	6-pt Likert scale
Attitude	6. Motorists who do not follow traffic laws pose a serious threat to pedestrian safety.	6-pt Likert scale
Attitude	7. Keeping pedestrians safe is an important part of my job.	6-pt Likert scale
Attitude	8. Pedestrian laws are difficult to enforce.	6-pt Likert scale
Resources/capacity	9. My colleagues/ I have adequate resources to use toward making our community safer for pedestrians.	6-pt Likert scale
Resources/capacity	10. I have the support of my command staff to perform pedestrian safety operations.	6-pt Likert scale
Resources/capacity	11. There is NOT enough pedestrian-focused training available that can help me do my job better.	6-pt Likert scale
Self/Unit efficacy	12. My department/unit could perform a pedestrian crossing operation.	6-pt Likert scale
Response efficacy	13. Enforcing pedestrian safety is a worthwhile endeavor.	6-pt Likert scale
Self/Unit efficacy	14. On an average shift, I do not have time to enforce laws to protect pedestrians.	6-pt Likert scale
Response efficacy	15. If I enforce pedestrian safety laws, more drivers will yield to pedestrians in marked crosswalks.	6-pt Likert scale
Response efficacy; Stage of change (pre-contemplation-believer); attitude	16. I can help prevent crashes by enforcing pedestrian/motorist laws.	6-pt Likert scale
Stage of change (pre-contemplation-non-believer); attitude	17. Pedestrian safety does not need routine enforcement.	6-pt Likert scale
Stage of change (contemplation)	18. I have been thinking that my unit should work on planning a crosswalk enforcement operation within the next 6 months.	6-pt Likert scale
Stage of change (preparation)	19. During the next 6 months, I plan to routinely enforce drivers yielding at crosswalks.	6-pt Likert scale
Stages of change (action)	20. It is likely that my unit/department will enforce pedestrian laws regularly during the next 6 months.	6-pt Likert scale
Demographics	21. How long have you been in law enforcement?	Fill-in
Demographics	22. What is your rank or class title?	Fill-in
Demographics	23. Do you have the authority to make decisions regarding whether or not to perform pedestrian safety enforcement	6-pt Likert scale
Demographics	24. Squad/unit type	Multiple Choice
Demographics	25. Work setting	Multiple Choice
Demographics	26. What other pedestrian-focused enforcement training have you received before this workshop (please circle all that apply)	Multiple choice

4.2.6 Observational Data

Aim 2.3 will employ observational data of driver behaviors collected at a sampling of crosswalks in the study area. Since pedestrian crashes are relatively rare events for any limited geographic area or short time period, direct behavioral measures will serve as a more appropriate outcome measure for evaluating the effectiveness of the intervention in changing behaviors that can lead to crash prevention.

Field data were repeatedly collected by HSRC staff at 12 public street crossings in Raleigh and Durham from July 2012 to February 2013. The sites were selected based on the following criteria:

1. Identified through 5-year crash analysis as high pedestrian crash sites
2. Posted speed limit was at or below 35 MPH
3. Crossings were located at unsignalized intersections or midblock locations
4. A marked crosswalk was present (high visibility or continental style markings)
5. The site was considered a safe/secure place for data collectors
6. No construction was planned that would affect the infrastructure at the site
7. The site was likely to receive a law enforcement operation
8. The site experienced adequate pedestrian traffic for conducting naturalistic observations

At each site, observed measures of driver behavior (including yielding, close stopping, hard breaking, attempted passing, and conflicts) were collected by two trained data collectors following specific, well-established protocols (Van Houten et al., 2013). The protocols provided a standardized way to observe both naturalistic and “staged” pedestrian crossings (i.e., interactions with motor vehicles) at the sites on dry-weather weekdays during day light hours.

Naturalistic crossings were observed, where pedestrian activity was high, in order to capture realistic pedestrian and driver interactions in an uncontrolled setting. To complement these, staged crossings were performed by the trained data collectors using a standardized crossing process in order to provide a consistent test of driver behavior under more controlled circumstances than naturalistic conditions could offer. Staged crossings were designed to control certain conditions, including pedestrian volumes and pre-crossing behaviors, and achieve a higher sampling of pedestrian-driver interactions given the time available for data collection. For both types of crossings, several quality assurance and control measures were put in place to ensure high quality and consistent data collection. These included a three-part training program for the data collectors, including the provision of written protocols, in-class training with visual examples and crossing scenarios, and field-based practice at actual data collection sites. It also included routine, weekly checks on the data collector operations to confirm fidelity to protocols and personal review of the data to check for inaccuracies and inconsistencies in data coding. Although weather-dependent, the data collection schedule aimed for consistency in the time of day and the day of week that each site was visited to help control for environmental effects. Similarly, while data collectors occasionally had to be substituted due to illness or personal schedules, the plan consistently used the same two primary data collectors from August to March to limit confounding due to individual differences in data collection or crossing behaviors. Finally, inter-rater reliability tests were performed at select sites (where natural crossing volumes were highest) and are planned for Year 2 as well. See Appendix E for the detailed observational data collection protocols and Appendix F for the observational data collection forms.

A total of 9,523 crossing events were observed at the 12 sites from 7/12-3/13 (see Table 8). For Year 2 of the intervention, data will be collected at 16 sites in 10+ waves from 8/13-1/14, resulting in 6,400 – 9,600 new crossing observations, plus additional natural crossings. The 16 sites include most of the original 12 sites in Raleigh and Durham, though some were dropped due to failure to meet the original selection criteria listed above. New sites were added in Chapel Hill, Carrboro, and Fuquay-Varina at the request of the sponsoring agency.

Table 8. Summary of pedestrian crossing events observed during four intervention waves in year 1.

Site	Pre-Education			Pre-Enforcement			During/Post-Enforcement			After			Total Natural	Total Staged	Grand Total
	Natural	*Staged*	*Sub-Total*	*Natural*	*Staged*	*Sub-Total*	*Natural*	*Staged*	*Sub-Total*	*Natural*	*Staged*	*Sub-Total*			
Durham Sites															
Anderson @ Yearby	25	150	175	38	175	213	25	325	350	1	75	76	89	725	814
Fayetteville @ Pekoe	52	150	202	61	150	211	74	375	449	11	100	111	198	775	973
Gregson @ Lamond	0	125	125	3	175	178	4	350	354	5	75	80	12	725	737
Main @ Brightleaf	41	150	191	31	175	206	38	325	363	10	75	85	120	725	845
Riddle @ Tobacco	4	150	154	11	175	186	14	350	364	7	75	82	36	750	786
University @ Chapel	40	150	190	22	175	197	9	150	159	5	75	80	76	550	626
Raleigh Sites															
Blount btw Hargett and Martin	61	150	211	47	175	222	90	350	440	18	50	68	216	725	941
Martin @ Bloodworth (pre-Stop)	1	150	151	4	175	179	1	125	126	--	--	--	6	450	456
Martin @ Bloodworth (post Stop)	--	--	--	--	--	--	2	175	177	0	25	25	2	200	202
Martin @ State St	6	146	152	7	175	182	3	300	303	0	25	25	16	646	662
South btw Salisbury and Wilmington	10	124	134	7	175	182	9	325	334	2	25	27	28	649	677
Wilmington @ the Capitol	36	150	186	17	175	192	20	350	370	5	50	55	78	725	803
Wilmington btw Hargett and Martin	85	150	235	62	175	237	107	350	457	22	50	72	276	725	1,001
Grand Total	**361**	**1,745**	**2,106**	**310**	**2,075**	**2,385**	**396**	**3,850**	**4,246**	**86**	**700**	**786**	**1,153**	**8,370**	**9,523**

4.3 Analysis Approach

Table 9 provides an overview of the analysis methods proposed for each of the seven sub-aims, which are further described in the sections below. For Aim 1 (characterize the nature of pedestrian crashes), the candidate will perform a descriptive analysis of pedestrian crash reports from two primary sources: DMV crash reports and emergency data reports. Analyses will examine:

- Measures of impact/burden by different population sub-groups, including age-groups, males/females, and various ethnicities
- Temporal and seasonal distribution of crashes and/or crash rates, including crash frequency by day, hour, and month
- Relation to economic factors, including unemployment, education, household vehicle ownership, and household income

For Aim 2 (evaluating the intervention targeting driver and pedestrian behaviors), the candidate will use multiple methods, including a descriptive analysis of program implementation measures, a paired-sample t-test of self-reported measures before and after the intervention, a time-series regression of driver yielding behaviors, and a pre-post analysis of pedestrian crash rates. Comparison groups, when applicable, will be utilized to strengthen the analysis. SAS (Statistical Analysis Software, SAS Institute, NC) will be used for all of the proposed analyses.

Table 9. Summary of anticipated analytical methods.

Aim	Data Set	Comparison Group	Analysis Method
1.1 (DMV)	2,220 police reported crashes per year statewide and Block-group level Census data	N/A	Descriptive analysis and negative binomial regression
1.2 (ED)	Patient data from 2007 to present from 100+ 24/7 hospital-based EDs	N/A	Descriptive analysis
2.1 (Implementation)	Program implementation measures (see Table 6) from 10 municipalities and 8 universities	N/A	Descriptive analysis
2.2 (Self-report)	Data from 55 police officers surveyed in 2013	N/A	Paired sample t-test on the differences between pretest and posttest scores
2.3 (Behavioral)	9,500+ crossing events were at 12 treated and untreated sites from 7/12-2/13. 6,400+ crossing events will be observed in 2013-2014 at 16 treated and untreated sites	Sites that did not receive active enforcement	Two group interrupted time-series regression analysis of driver yielding, using GEE to account for clustering
2.4 (Crash)	Roughly 400 crashes per year in the Triangle; 2,200 statewide	Statewide, Mecklenburg County, and the 7-County “Triad” region	Before-after comparison of crash rates using negative binomial regression

4.3.1 Aim 1.1 Approach

This sub-aim will involve performing a descriptive analysis to characterize the seasonal, demographic, and injury severity distribution of the DMV crash data. Mean, Median, and SD descriptive statistics will be provided for relevant continuous variables listed in Table 3. Crash distributions (totals and %) will be provided by relevant categories for nominal or ordinal variables in Table 3. Crash incidence frequencies and rates per population will be generated for each county in NC. Crash incidence by arrival date and time will also be calculated. Chi-square statistics will be used for cross-tabulated data comparisons.

The second part of this sub-aim will involve merging records with Census block group characteristics to pedestrian crash data to produce counts of pedestrian crashes by block group. Counts, rather than crashes per population, will be used as the dependent variable so as not to assume a linear relationship between number of crashes and population size (Chen et al., 2011). Negative binomial regression will be used to model the relationship between census block group characteristics and pedestrian crash counts. This model is appropriate for modeling over-dispersed count data as an outcome, (i.e., when the conditional variance exceeds the conditional mean). The residential population density of the block group will be used as the offset variable. Using the model results, adjusted rate ratios for each quartile of key variables will be calculated.

Goodness of fit of the model will be assessed by considering the deviance (value/degrees of freedom). The deviance should be within the range of 0.75 and 1.25 to ensure that the model is a good fit for the data. This negative binomial model implies a distribution of crashes as such:

$$\Pr(X = k) = \left(\frac{r}{r+m}\right)^r \frac{\Gamma(r+k)}{k!\,\Gamma(r)} \left(\frac{m}{r+m}\right)^k \quad \text{for } k = 0, 1, 2, \ldots .$$

Where k is the number of pedestrian crashes in each block group, Γ is the gamma function, r is the dispersion parameter, and m is the mean or expected value of k. For this study, k will be expressed as a function of block group level population characteristics.

The candidate will assess colinearity between socioeconomic characteristics using Pearson's product-moment correlation coefficients. This approach has been taken in other similar studies (Chakravarthy et al.). The aim of assessing colinearity is to be aware of variables that may be highly correlated prior to beginning the modeling process and to use regression diagnostics to explore any problems further during modeling. Model results will be presented in terms of the variables and their estimated coefficients, pseudo T value for maximum likelihood estimators (Z Value), and over-dispersion parameter.

4.3.2 Aim 1.2 Approach

This sub-aim will involve performing a descriptive analysis to characterize seasonal, demographic, and injury severity distribution of the ED crash data. Crash incidence frequencies and rates per population will be generated for each county. Crash incidence by arrival date and time will also be calculated. Patient injury characteristics, including chief complaint, disposition, and diagnosis code, will be compared by age and sex, using a student t-test to compare differences for the continuous variable (age) and a chi-square statistic for the categorical values (sex). Patient characteristics will be presented in tables and alpha levels and 95% confidence intervals will be included for all relevant statistical tests.

4.3.3 Aim 2.1 Approach

The analysis approach for this aim is descriptive in nature and will summarize the intervention measures implemented as identified in the implementation records described in Table 6. Using both the quantitative and qualitative data provided by the partners, the candidate will discuss strengths and challenges in implementing behavioral interventions to promote pedestrian safety.

4.3.4 Aim 2.2 Approach

A pretest-posttest comparative design will be used to evaluate the outcome of implementing a training program for law enforcement professionals on pedestrian and bicycle safety. Pre-tests will be matched to post-tests for each individual. A t-test procedure will be used to compare mean changes in scores, and 95% confidence intervals will be constructed. Results will be grouped by domain and stratified by officer location (campus vs. municipality), previous training, and years of experience.

Out of the 55 survey respondents, 52 attended the full training course, while 3 only attended one day of the two-day course. The analysis will assume that all law officers were equal participants in the intervention training course, regardless of whether they attended both days of the course.

4.3.5 Aim 2.3 Approach

An interrupted two-group time-series regression analysis of driver yielding behaviors will be performed in Aim 2.3. Time-series analysis is a commonly used approach to evaluate interventions, particularly in the field of traffic safety (Biglan et al., 2000; Gruenewald, 1997; McLeod and Vingilis, 2008). A time-series approach will help account for trends, seasonality, and temporal or geographic auto-correlation in the behaviors observed. Generalized Estimating Equations (GEE) are an appropriate modeling technique when working with binary outcomes and counts (such as driver yielded/did not yield or counts of yielding) as well as time-dependent covariates and continuous or categorical explanatory variables (Stokes et al., 2000). In this study, GEE will be used to account for within-cluster correlation, since crossing events observed are clustered at the 12-16 crossing sites, as well as adjust for covariates such as speed limit, crosswalk marking type, and other environmental features known to impact driver behaviors.

Before modeling occurs, raw data will be plotted to be sure that there are enough data points and to explore trends before and after the intervention. The goodness of the model fit will be tested using QIC statistics to assist in model building and to identify the most predictive variables. Both unadjusted and adjusted difference in driver yielding rates will be presented along with model outputs.

The association between the intervention and driver yielding will be modeled for each site individually and in aggregate. Each model will include a term for the intervention group (treated vs. untreated), four phases of time (i.e., before, pre-enforcement, during enforcement, and after), and a time by group interaction term. It will also include covariates such as the characteristics of the site mentioned above and a measure of time (month) to account for seasonal trends. A second, more nuanced model may be created to include a term to account for the "intensity" of the enforcement efforts at the treated sites if large discrepancies exist. The 16 sites will be operationalized as clusters in the repeated statement. An exchangeable working correlation specification will be used; this structure is commonly accepted when cluster sampling is involved (Stokes et al., 2000). Robust standard errors will also be used.

The intervention group (sites receiving the enforcement intervention) will be compared to a control group to strengthen the study design. The control sites will be defined as those that did not receive active enforcement during the intervention period. The physical characteristics of the control sites (such as speed limit, traffic volumes, crosswalk type, etc.) are largely the same as the treatment sites, as both were selected using the same criteria described above. Law enforcement departments, based on internal resources available, selected a few of the sites for active enforcement using no systematic process. Therefore, the sites chosen for treatment or control are considered largely to have been naturally randomly selected. Although only treated sites will have received enforcement actions, both treatment and comparison sites have the potential to be affected by spill-over as a result of the media and outreach campaign. Due to the concurrent timing of the media outreach and the enforcement activities, it will be impossible to disentangle the effects of only the enforcement activities at any site.

4.3.6 Aim 2.4 Approach

The candidate will estimate the DMV-reported pedestrian crash incidence rate per 1,000 population in the Triangle area in comparison to other non-intervention comparison locations. The Triangle region "treatment" group will be defined as Wake, Orange, and Durham Counties. Multiple comparison groups will be used to help remove the effects of any pre-existing crash trends that could mistakenly be attributed to the intervention. Potential comparison groups include all of North Carolina, Mecklenburg County, and the 7-County "Triad" region. The use of multiple comparison groups is an approach taken in other studies

(Zegeer et al., 2008) to accommodate the fact that there is no single community that would be comparable in all dimensions to the Triangle pedestrian crash experience.

Both the Triad and Mecklenburg County are largely metropolitan areas that have similar roadway facilities and population demographics to the Triangle, but vary in their municipal government make up and the total number of crashes experienced per year and pedestrian crash rate (see Table 10). Also, both the Triad and Mecklenburg County residents are in separate media markets, meaning that there would be less potential for spillover effects of the intervention public outreach and media in the Triangle. Since many macro-trends (such as the economy and transportation policies occurring at the state-level) may also be affecting walking and driving rates and crash rates and may confound the intervention effects, the State is also considered an appropriate comparison group.

Table 10. Summary of comparison group community characteristics.

Dimension	Triangle (Treatment Group)	Comparison Option #1: Mecklenburg	Comparison Option #2: Triad	Comparison Option #3: Statewide
Total population	959,778	871,406	886,051	9,535,483
Number of counties	3	1	8	100
Number of cities	10	7	22	348
Total # of crashes per year	361	375	283	2509
Average total # of crashes per city	181	268	64	28
Collective 5-year crash rate	1.88	2.15	1.59	1.32
ACS Walk to Work (2007-2011 5-yr estimate)	1.60%	1.90%	1.75%	1.80%

A five-year pedestrian crash rate average will be calculated for each of the above groups for the time period of 2006-2010 as the "before" intervention period. These will be compared to the 2011 and 2012 two-year "after" period using negative binomial regression, following a similar approach as the one outlined in Aim 1.1.

4.4 Study Timeline

The timeline for the data collection and analysis is provided in Table 11. Data related to both aims will be collected from July through February and analysis will begin in 2014. A dissertation defense is expected by December 2014.

Table 11. Study timeline.

Aim	Description	Timeframe
Both	Finalize study design plan and refine data collection instruments	July/August 2013
Both	Implement interventions	Ongoing thru January 2014
2	Provide training to law enforcement and distribute questionnaire	July 25 – August 2
2	Collect year 2 data on driver yielding and pedestrian behaviors	Late August 2013 – February 2014
Both	Present/defend dissertation proposal	September 24, 2013
1	Gather/process census, crash, and ED data	Fall 2013
Both	Process all field and program implementation data and begin analysis work	December 2013 – July 2014
Both	Manuscript preparation	August 2014 – November 2014
Both	Dissertation defense	December 2014

Regarding manuscript preparation, Table 12 provides a plan for the proposed target journal and tentative submission dates for each applicable aim. The candidate will aim to contribute to the broader biomedical and public health literature, beyond the traditional traffic safety field. A minimum of one paper, and ideally two, will be submitted before the final defense date.

Table 12. Manuscript development timeline.

Aim	Manuscript Title	Proposed Target Journal(s)	Proposed Backup Journal(s)	Tentative Submission Date
1.1 and 1.2	Descriptive Epidemiology of Pedestrian Crashes in North Carolina	NC Medical Journal	Transportation Research Records; Accident Analysis & Prevention	September 2014
1.1	Socio-economic Characteristics of Pedestrian Crashes in North Carolina	American Journal of Public Health	Social Science & Medicine; Journal of Epidemiology and Community Health	October 2014
2	Evaluation of a a Community-Based Intervention to Prevent Pedestrian Injury through a Multi-Method Approach	Epidemiology; American Journal of Epidemiology	Accident Analysis & Prevention; Injury Prevention; International Journal of Injury Control and Safety Promotion; Transportation Research Records	November 2014

4.5 Human Subjects

An IRB application was submitted and reviewed by the Office of Human Research and Ethics and received a notice of IRB Exemption (study # 13-2567). Efforts are in place to protect all human subjects and field data collectors involved in this research.

5. DISCUSSION

5.1 Study Strengths and Contribution to Public Health

Aim 1 of this study will extend our knowledge of the descriptive epidemiology of pedestrian crashes occurring in North Carolina. It will document the incidence of pedestrian injuries and fatalities in a well-defined large population (NC residents). Aim 1 will utilize recent, population-based data from multiple sources. An emphasis on identifying socioeconomic correlates to pedestrian crashes and injuries will be a unique contribution to the literature. Recent studies have raised light on disparities in pedestrian injury by socioeconomic status (Cottrill and Thakuriah, 2010; Kravetz and Noland, 2012; Wier et al., 2009), but these studies have been limited to small regions or single cities (such as Northern New Jersey, Chicago, and San Francisco) that may experience less socioeconomic variation than a larger state-level geography. To the extent possible, Aim 1 will rely on a conceptual model to select the measures of SES used. The model will account for multiple dimensions of SES, acknowledging the complex nature of socio-economic issues and their relation to pedestrian crash outcomes.

For Aim 2, this study will quantify the effect of a community-based pedestrian safety interventions. Aim 2 will evaluate an intervention designed to impact pedestrian safety at a regional scale. The documentation of the intervention implementation (in Aim 2.1) and process measures, in combination with driver behavior data and crash data, will be of particular use to transportation and public health practitioners seeking information and guidance regarding intervention planning and evaluation. The approach to Aim 2 combines multiple sources of data to comprehensively and scientifically evaluate a multi-faceted pedestrian safety intervention. This will provide insights into different aspects of the intervention and how each may be contributing toward the expected outcomes. Relatively few comprehensive (addressing multiple outcomes, e.g. driver behavior, crash data) evaluations have been conducted. Because it is based in a real-world setting, this study will estimate true intervention effectiveness (as opposed to efficacy). An additional strength of this study (Aim 2.3) is the use of repeated-measures of observable behaviors at both treated and non-treated sites to document changes in behaviors over time, rather than simple one-time before and after measures used in previous studies. An approach using GEE to account for clustering at the sites and the use of a case and control series to adjust for trends will address some of the weaknesses of prior studies that have rarely controlled for potential confounders. Similarly, the use of control groups to examine changes in pedestrian crash rates (in Aim 2.4) is rarely seen in existing pedestrian program evaluations. The results of this effort will provide an estimate of self-reported, behavioral, and crash-based outcomes associated with the intervention.

By providing valid estimates of the impact and outcomes of the intervention, this study will aid decision-makers at both the state and local level in determining the need for further investment in pedestrian safety interventions such as the Watch for Me NC program. The timing of this study is significant, given that NCDOT officials are considering whether to scale up the Watch for Me NC model to become a statewide program in 2014 or beyond.

5.2 Study Limitations

Like any research effort, the study has some limitations. In Aim 1.1, a variety of unmeasured confounders could potentially affect the results. These include the safety culture and risk taking behavior of the population of interest, the type and quality of roadway facilities, and measures of “exposure” to vehicle traffic. Routine and high-quality pedestrian exposure data does not exist for the area of study. Thus, the candidate proposes to use population density as a control, which is a less accurate but more readily available measure of pedestrian exposure. Use of population data makes the assumption that all individuals in any population are equally exposed (due to time traveled or to distance walked) to the risk of a pedestrian crash. This assumption is commonly accepted in existing literature (Chen et al., 2011; Morency, et al., 2012). Another potential concern in Aim 1.1 is that the negative binomial modeling approach does not take into account the potential spatial auto-correlation of the pedestrian crashes. This limitation has been noted in other similar studies as well (Kravetz and Noland, 2012; Cottrill et al., 2010).

Finally, because Aim 1.1 focuses on a block-level pedestrian crash model, inferences regarding socio-economic correlations can only be made at the block group level, not at the individual level. Block-group variables used in the model may not account for confounding by variables at the individual level (the so-called “ecologic fallacy”). Similarly, a common concern raised is that a pedestrian involved in a crash in one block-group may actually reside or work in another part of the community and have limited affiliation to the socio-economic characteristics of that block group. This concern is partially mitigated by research that has examined the relation of pedestrian residence to distance from the collision site (Anderson et al., 2012). This study, examining patients reporting to a Level 1 Trauma Center, found that 48% of pedestrian collisions occurred within 1.1 km of the victim’s home, with a median distance between collision and residence of 1.4 km. The median distance did not differ by sex, race, or ethnicity. Forty four percent were injured within the same census tract as their home or on the boundary line of their home, while the remaining 55% were injured in a different census tract. The research found that more severe injuries typically occurred further from the victim’s home, while older and younger pedestrians (above 65 years or below 17 years) were typically injured closer to home (a finding that likely reflects walking patterns for older adults).

Aim 2.1 will utilize intervention implementation records to measure the strength and reach of the intervention. This approach is limited in that it is time-intensive and dependent on the partner organizations to provide quality and complete data. More than 20 agencies are actively involved in the two-year effort, each with multiple departments and staff. Not all partners have been responsive to requests for information, so it is likely that the summary of intervention intensity will be under-representative of the myriad of activities taking place. Other methods are available that could have strengthened this aspect of the evaluation. For example, other studies have employed partnership capacity surveys, concept mapping, progress reporting, key informant interviews, focus groups, environmental audits, and direct observation to document intervention activities being performed at the community level (Brownson et al., 2012). Unfortunately, these methods are beyond the scope of this effort.

The quasi-experimental nature of the evaluation in Aim 2 is another limitation. The intervention evaluation is led by diverse community partners in a real-world setting, and thus it will not be possible to fully control the intervention implementation or utilize randomization in any analysis approaches to strengthen the study design. As noted in the methods section, other approaches will be utilized—such as the use of comparison groups and adjusting for covariates—to mitigate the influence of potential temporal or other confounders and strengthen the study design. A fully randomized design would require a significant investment of research resources.

Fortunately for the region of interest, pedestrian crashes remain relatively rare. For this study, however, a rare outcome means limited or sparse data that reduce the overall power of statistical approaches or limit the type of robust analyses that can be performed. Efforts have been made to utilize as much crash data as can be obtained for the relevant aims (1.1, 1.2, and 2.4), both by expanding the geographic scope of crash data considered to statewide (Aim 1.1), including crash data from different sources (DMV and EDs), and by expanding the time period of pedestrian crashes to multiple pre-intervention years (for Aim 2.4).

The ideal denominator to use in our rates analyses would be data on time spent walking on roadways or miles traveled by foot. However, data on exposure to roadway walking (pedestrian exposure data) is expensive to collect and will not be available for any portion of this analysis. Crash rates that use population density as the denominator provide a less accurate but more readily available surrogate measure of pedestrian exposure. The use of population data requires the assumption that all individuals in any population are equally exposed (due to time traveled or to distance walked) to the risk of a pedestrian crash. The crash analysis portion of the evaluation (Aim 2.4) would particularly benefit from having more accurate measures of pedestrian exposure (the denominator value for the "crash" event numerator) to better estimate crash rates.

Finally, because the evaluation in Aim 2 is only measuring the first and second year of an intervention, it may underestimate the programs' full or long-term impact. Many important elements in pedestrian crash prevention that this intervention aims to accomplish indirectly, such as policy changes and modifications to the built environment, may require more time to achieve. Ideally, future research should provide additional time for post-intervention follow-up to better examine long-term impacts.

5.3 Summary

In conclusion, the incidence and associated costs of pedestrian injuries and fatalities resulting from motor-vehicle collisions is a significant public health burden, particularly for vulnerable populations such as minorities or low-income neighborhood residents. The epidemiology of pedestrian crashes has not been well defined and limited research is available that quantifies the effectiveness of pedestrian injury prevention interventions, resulting in a lack of guidance to support intervention development and a limited evidence-base to support intervention implementation.

The proposed study is novel in its use of multiple, recent, population-wide data sources that are unique to North Carolina, including statewide ED data as well as a statewide database of detailed and geo-coded pedestrian crash data. Similarly, it is one of the first in the field to scientifically evaluate a pedestrian safety intervention using a comprehensive set of measures, including intervention implementation records, self-report, observational behavior, and crash-based measures. The use of control groups to examine changes in driver behaviors and crash rates and robust modeling techniques to adjust for potential confounders, including negative binomial regression and GEE methodology, is a key strength not found in existing pedestrian intervention evaluation literature.

The results of this study will provide information about the incidence and correlates of pedestrian injuries and fatalities, as well as insights into the nature of those injuries and the relationship between crashes and socio-economic factors, which has never before been examined for this population. It will also provide evidence of the effectiveness of community-based, comprehensive pedestrian interventions that will aid decision-makers at both the state and local level in determining the need for further investment in such programs. Ultimately, information about the epidemiology of pedestrian crashes and the effectiveness of targeted interventions can assist in guiding future improvements that both prevent unintentional injury and help promote the use of active transportation and the myriad of public health co-benefits that active transportation offers.

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8. APPENDIX A: AVAILABLE DMV DATA VARIABLES

Below is a list of all available variables from DMV pedestrian crash data. Highlighted rows indicated variables selected for use in the proposed study.

Attribute	Example(s)
Crash ID	102112860
Latitude	35.857500
Longitude	-78.581700
Pedestrian Age	46
Pedestrian Sex	Male, Female
Pedestrian Race	Black, White, Hispanic, Asian
Pedestrian Alcohol Use	No
Pedestrian Injury	K,A, B, C, O
Driver Age	21
Driver Sex	Male, Female
Driver Race	Black, White, Hispanic, Asian
Driver Alcohol Use	No, Yes
Driver Injury	K,A, B, C, O
Driver Vehicle Type	Passenger Car, Pick up, Sport Utility
Driver Speed	Unknown, 0-5mph, 41-45 mph
Crash Location	Intersection, Intersection-Related, Non-Roadway
Pedestrian Position	Travel Lane, Non-Roadway, Crosswalk Area
Crash Type	Backing Vehicle, Parking Lot, etc.
Crash Alcohol (Ped or Driver Use)	No, Yes
Ambulance Required	No, Yes
City	Raleigh
County	Wake
Work zone	No, Yes
Crash Severity	K,A, B, C, O
Crash Date	10Aug2008
Driver Level	Commercial, Residential
Fault	Unknown, Motorist, Pedestrian
Hit and Run	No, Yes
Light Conditions	Daylight, Dark – Roadway Lighted, Dark – Roadway not Lighted
Locality	Urban (>70% developed)
Number of Lanes	Unknown, 2, etc.
Roadway Characteristics	Straight - Level
Road Classification	Public Vehicular Area, Local Street
Road Conditions	Dry, Wet
Road Surface	Smooth Asphalt, Coarse Asphalt
Roadway Features	Four-Way Intersection, Driveway – Public, etc.
Road Configuration	Two-way, Not Divided, etc.
Traffic Control	No control present; stop and go signal
Weather Conditions	Clear
Speed Limit	5-15 MPH, 40-45 MPH
Rural or Urban	Urban
Crash Year	2008
Time of Day	16:08
Hour of Day	16
Crash Month	October
Crash Day of Week	Friday

Attribute	Example(s)
Excess Speed	No, Yes
Region	Piedmont

9. APPENDIX B: AVAILABLE ED DATA VARIABLES

Below is a list of all available variables from NC Detect's Emergency Department data. Highlighted rows indicated variables selected for use in the proposed study. The table content was sourced directly from: http://ncdetect.org/dataelements.html.

Name	Description/Notes
Internal Tracking ID	NC DETECT-generated identifier that uniquely identifies a patient at that healthcare facility/system. Can be used to track repeat visits by the same patient to the same facility/system
Patient Age	Available in years
Sex	M (Male), F (Female), U (Unknown)
Patient City	Patient's city of residence
Patient County	Patient's county of residence
Patient ZIP	Patient's ZIP of residence (5-digit)
Patient State	Patient's state of residence
Visit ID	NC DETECT-generated identifier that uniquely identifies that ED visit
Hospital	Emergency department facility where patient sought care
Insurance Coverage (or Other Expected Source of Payment)	Entity or person expected to be responsible for patient's bill for this ED visit (private insurance, self-pay, Medicare, Medicaid, etc.)
Arrival Date and Time	First date and time documented in patient's record for this ED visit
Transport Mode	Patient's mode of transport to ED (walk-in, ground ambulance, etc.)
Chief Complaint	Patient's reason for seeking care or attention, expressed in terms as close as possible to those used by patient or responsible informant
Triage Notes	Supporting information for Chief Complaint
Blood Pressure	Blood pressure taken at triage (when available)
Initial Temperature	Temperature taken at triage (in Celsius)
Injury Code(s)	Encoded description of injury event that precipitated patient's ED visit; ICD-9-CM E code(s)
Disposition	Patient's anticipated location or status following ED visit (discharged, admitted, transferred, died, etc.)
Disposition Diagnosis Description	Practitioner's description of condition or problem for which services were provided during patient's ED visit, recorded at time of disposition
Diagnosis Code(s)	Up to 11 ICD-9-CM Final Diagnosis Codes

10. APPENDIX C: LAW ENFORCEMENT CITATION DATA FORMS

Year 1 Data Collection Form

UNC Highway Safety Research Center is in the process of evaluating the effectiveness of the Watch for Me NC pedestrian safety education and enforcement program. We are also tasked with documenting all aspects of the campaign to provide a model for other communities. Following is information that we would like to have from your department related to **each enforcement activity conducted**:

Date of operation: ____________________Total Number of Officers Involved:_____________________
Officer in charge:____________________________Unit/District:_________________________________
Site of enforcement (intersection or nearby crossroads):_______________________________________
Time active enforcement began:______________ __ Time active enforcement ended:_______________

Number of "Failure to Yield to Pedestrian" **Oral Warnings** issued:________________________________
Number of "Failure to Yield to Pedestrian" **Written Warnings** issued:_____________________________
Number of "Failure to Yield to Pedestrian" **Citations** issued:____________________________________

Number of "Speeding" **Oral Warnings** issued:____
Number of "Speeding" **Written Warnings** issued:____
Number of "Speeding" **Citations** issued:____

Warnings issued to pedestrians (please list type of violation and number given):

____
____
____

Citations issued to pedestrians (please list type of violation and number given): ___________________
____
____

Any other relevant warnings or citations given, including "Failure to Stop" "Aggressive/Reckless Driving" and "Alcohol-related Offenses" (please list type and number given): _______________
____
____

Please return completed forms to Laura Sandt at sandt@hsrc.unc.edu or contact her at 919-962-2358 to arrange collection by HSRC staff.

Year 2 Data Collection Form

UNC Highway Safety Research Center needs your help in monitoring and evaluating the effectiveness of the Watch for Me NC pedestrian and bicycle safety education and enforcement program. **Please provide the following information for each enforcement activity conducted by your department**:

Date of operation: _________________Total Number of Officers Involved:_______________________

Officer in charge/contact person:_________________________Unit/District:______________________

Site of enforcement (intersection or nearby crossroads):____

Time active enforcement began:_______________Time active enforcement ended:__________________

Motorist violations issued:

	Verbal Warnings	Written Warnings	Citations	Total Contacts
Failure to yield to pedestrian in crosswalk				
Speeding				
Failure to yield to cyclist or pedestrian when turning				
Unsafe passing				
Aggressive/reckless driving				
Alcohol-related offenses				
Other				

Warnings issued to pedestrians (*please list type of violation and number given*):

____

____

Citations issued to pedestrians (please list type of violation and number given):

____

____

Warnings issued to bicyclists (please list type of violation and number given):

____

____

Citations issued to bicyclists (please list type of violation and number given):

____

____

Describe the measures used to raise public awareness of the operation (i.e., use of sandwich board signs, public postings, media advisories/press releases, etc.):

____

____

Number of materials distributed during operation:

Brochures	Bike Lights	Bracelets	Other

Please return completed forms to Laura Sandt at sandt@hsrc.unc.edu **or contact her at 919-962-2358 to arrange collection by HSRC staff.**

11. APPENDIX D: LAW ENFORCEMENT QUESTIONNAIRE (YEAR 2)

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

You are invited to take part in a research study being conducted by the Highway Safety Research Center at The University of North Carolina at Chapel Hill, investigating the effectiveness of the Watch for Me NC pedestrian safety program. You are being asked if you want to take part in this study because you are a participant in a training class offered as part of that program. Participation is voluntary and you can quit at any time. Your decision to take part or not will not affect the services or benefits provided to you as part of the Watch for Me NC program. The completion of this questionnaire should only take about 10 minutes or less of your time. There are no known risks to participating in this study. The information you provide will not be identifiable and the records will be kept private.

This study (#13-2567) has been reviewed and approved by the Office of Human Research Ethics. If you have questions or concerns about your rights as a research participant, you may contact the Institutional Review Board at 919-966-3113 or by email to IRB_subjects@unc.edu. If you have any questions or comments you may also contact the Principal Investigator of this study, Laura Sandt, who can be reached at (919) 962-2358 or at sandt@hsrc.unc.edu. Your willingness to participate in this research study is implied if you proceed with completing any of the following questions.

Thank you for your time and participation in the Watch for Me NC program.

PRE-WORKSHOP QUESTIONNAIRE

For questions 1-4, please circle only ONE answer from the choices available.

1. A motorist approaching a person stepping off a curb at an uncontrolled intersection should:
    - A. Slow down or stop until the pedestrian crosses to the other side of the roadway
    - B. Honk his/her horn to alert the pedestrian of their presence
    - C. Change lanes, if possible, to get around the pedestrian
    - D. Alert the local police to safety issues posed by jaywalkers
    - E. I don’t know

2. When is it legal for a pedestrian to cross a street <u>mid-block</u>?
    - A. Never
    - B. When there is enough room for cars to slow down for them
    - C. When they do not impede traffic and are not crossing between two adjacent signalized intersections
    - D. When they’re in a school zone or a commercial district
    - E. I don’t know

3. Which of the following statements is <u>NOT</u> a North Carolina Law?
    - A. When a sidewalk is available, pedestrians must use the sidewalk instead of walking on the roadway
    - B. When a vehicle is stopped for a pedestrian, motorists approaching from the rear may overtake and pass the stopped vehicle if the adjacent lane is clear
    - C. Motorists must yield the right-of-way to pedestrians when making a right turn on red
    - D. Pedestrians cannot impede the regular flow of traffic by willfully standing, sitting, or lying on the roadway

E. I don't know

4. What best describes the current pedestrian safety operation plans in your department/unit?
A. We have been performing pedestrian safety operations regularly for MORE than 6 months
B. We have been performing pedestrian safety operations regularly for LESS than 6 months
C. We intend to perform a pedestrian safety operation in the next 6 months
D. We intend to perform a pedestrian safety operation in the next year
E. We have no plans for conducting pedestrian safety operations in the next 6 months
F. I don't know or not applicable

For questions 5-20, please state your level of agreement or disagreement with each statement by circling one of the numbers on the right, using the scale below.

Disagree Completely	**Disagree Moderately**	**Disagree Slightly**	**Agree Slightly**	**Agree Moderately**	**Agree Completely**
1	**2**	**3**	**4**	**5**	**6**

5. I am familiar with the laws protecting pedestrian safety in North Carolina.	1	2	3	4	5	6
6. Motorists who do not follow traffic laws pose a serious threat to pedestrian safety.	1	2	3	4	5	6
7. Keeping pedestrians safe is an important part of my job.	1	2	3	4	5	6
8. Pedestrian laws are difficult to enforce.	1	2	3	4	5	6
9. My colleagues/ I have adequate resources to use toward making our community safer for pedestrians.	1	2	3	4	5	6
10. I have the support of my command staff to perform pedestrian safety operations.	1	2	3	4	5	6
11. There is NOT enough pedestrian-focused training available that can help me do my job better.	1	2	3	4	5	6
12. My department/unit could perform a pedestrian crossing operation.	1	2	3	4	5	6
13. Enforcing pedestrian safety is a worthwhile endeavor.	1	2	3	4	5	6
14. On an average shift, I do not have time to enforce laws to protect pedestrians.	1	2	3	4	5	6
15. If I enforce pedestrian safety laws, more drivers will yield to pedestrians in marked crosswalks.	1	2	3	4	5	6
16. I can help prevent crashes by enforcing pedestrian/motorist laws.	1	2	3	4	5	6
17. Pedestrian safety does not need routine enforcement.	1	2	3	4	5	6
18. I have been thinking that my unit should work on planning a crosswalk enforcement operation within the next 6 months.	1	2	3	4	5	6
19. During the next 6 months, I plan to routinely enforce drivers yielding at crosswalks.	1	2	3	4	5	6
20. It is likely that my unit/department will enforce pedestrian laws regularly during the next 6 months.	1	2	3	4	5	6

21. How long have you been in law enforcement?

____

22. What is your rank or class title?
____

23. Do you have the authority to make decisions regarding whether or not to perform pedestrian safety enforcement (please circle one)?

Yes No

24. Are you currently part of a (please circle all that apply):

Bicycle Squad Motorcycle Squad Vehicle Squad Other (specify):______________________

25. What setting do you work in (please circle one):

University/Campus Municipality County Other (specify):______________

26. What other pedestrian-focused enforcement training have you received <u>before</u> this workshop (please circle all that apply)?

The course last year at NCSU None Another course (specify):___________________________

POST-WORKSHOP QUESTIONNAIRE

For questions 1-4, please circle only ONE answer from the choices available.

1. A motorist approaching a person stepping off a curb at an uncontrolled intersection should:

    A. Slow down or stop until the pedestrian crosses to the other side of the roadway

    B. Honk his/her horn to alert the pedestrian of their presence

    C. Change lanes, if possible, to get around the pedestrian

    D. Alert the local police to safety issues posed by jaywalkers

    E. I don't know

2. When is it legal for a pedestrian to cross a street <u>mid-block</u>?

    A. Never

    B. When there is enough room for cars to slow down for them

    C. When they do not impede traffic and are not crossing between two adjacent signalized intersections

    D. When they're in a school zone or a commercial district

    E. I don't know

3. Which of the following statements is <u>NOT</u> a North Carolina Law?

    A. When a sidewalk is available, pedestrians must use the sidewalk instead of walking on the roadway

    B. When a vehicle is stopped for a pedestrian, motorists approaching from the rear may overtake and pass the stopped vehicle if the adjacent lane is clear

    C. Motorists must yield the right-of-way to pedestrians when making a right turn on red

    D. Pedestrians cannot impede the regular flow of traffic by willfully standing, sitting, or lying on the roadway

    E. I don't know

4. What best describes the current pedestrian safety operation plans in your department/unit?

    A. We have been performing pedestrian safety operations <u>regularly for MORE than 6 months</u>

    B. We have been performing pedestrian safety operations <u>regularly for LESS than 6 months</u>

    C. We intend to perform a pedestrian safety operation in the <u>next 6 months</u>

    D. We intend to perform a pedestrian safety operation in the <u>next year</u>

    E. We have <u>no plans</u> for conducting pedestrian safety operations in the <u>next 6 months</u>

    F. I don't know or not applicable

For questions 5-20, please state your level of agreement or disagreement with each statement by circling one of the numbers on the right, using the scale below.

Disagree Completely	Disagree Moderately	Disagree Slightly	Agree Slightly	Agree Moderately	Agree Completely
1	**2**	**3**	**4**	**5**	**6**

5. I am familiar with the laws protecting pedestrian safety in North Carolina.	1	2	3	4	5	6
6. Motorists who do not follow traffic laws pose a serious threat to pedestrian safety.	1	2	3	4	5	6
7. Keeping pedestrians safe is an important part of my job.	1	2	3	4	5	6
8. Pedestrian laws are difficult to enforce.	1	2	3	4	5	6
9. My colleagues/ I have adequate resources to use toward making our community safer for pedestrians.	1	2	3	4	5	6
10. I have the support of my command staff to perform pedestrian safety operations.	1	2	3	4	5	6
11. There is NOT enough pedestrian-focused training available that can help me do my job better.	1	2	3	4	5	6
12. My department/unit could perform a pedestrian crossing operation.	1	2	3	4	5	6
13. Enforcing pedestrian safety is a worthwhile endeavor.	1	2	3	4	5	6
14. On an average shift, I do not have time to enforce laws to protect pedestrians.	1	2	3	4	5	6
15. If I enforce pedestrian safety laws, more drivers will yield to pedestrians in marked crosswalks.	1	2	3	4	5	6
16. I can help prevent crashes by enforcing pedestrian/motorist laws.	1	2	3	4	5	6
17. Pedestrian safety does not need routine enforcement.	1	2	3	4	5	6
18. I have been thinking that my unit should work on planning a crosswalk enforcement operation within the next 6 months.	1	2	3	4	5	6
19. During the next 6 months, I plan to routinely enforce drivers yielding at crosswalks.	1	2	3	4	5	6
20. It is likely that my unit/department will enforce pedestrian laws regularly during the next 6 months.	1	2	3	4	5	6

Please provide any other comments or feedback regarding the law enforcement training course or your plans to conduct pedestrian safety operations:

____

____

____

____

____

Thank you for your time in attending this training and completing this form!

12. APPENDIX E: PROTOCOL FOR FIELD DATA COLLECTION (USED IN YEAR 1 AND 2)

Motorist Yielding Data Collection Procedures and Protocol

Adapted from original source material developed by Ron Van Houten[1]

When and Where to Collect Data

Data will only be collected on weekdays during dry conditions (i.e., no wet pavement) and clear visibility. Ideal data collection times are during peak travel times: 8:00-10:00AM, 11:30-1:30PM, and 3:00-5:00PM. A specific schedule of sites and times will be provided, as well as a range of dates in which data collection can occur.

Materials to Bring

When collecting data, data collectors will bring the following with them to each site:

- Measuring wheel
- 2 traffic cones for marking dilemma zones
- Protocols and data collection forms (Appendix A)
- Pens and pencils
- Clipboard (or something to write on)
- Watch
- Cell phone
- Photo identification
- Copy of study information sheet (Appendix B)
- Hat/Sunglasses or sunscreen if necessary
- Cash or coins for parking (if needed)
- Camera and/or video recording device (optional)
- Maps/GPS to navigate you to sites (optional)
- Lunch and plenty of water

Data collectors should wear normal, comfortable attire and comfortable shoes with closed toes and heel (i.e., no flip-flops). Neutral colored clothing is recommended. Some sort of "distraction" (i.e. a newspaper, book, cellphone) may be helpful for less busy or city crosswalks may be helpful in making staged pedestrian look more natural.

Calculation of the Dilemma Zone

Before collecting data, the research team will calculate the dilemma zone for each crosswalk site. Calculating the distance beyond which a motorist can safely stop for a pedestrian is essentially the same problem as calculating the distance in advance of a traffic signal that a motorist driving the speed limit can stop if the traffic signal changes to red. Traffic engineers use the signal-timing formula (Institute of Transportation Engineers, 1985), which takes into account driver reaction time, safe deceleration rate, the posted speed, and the grade of the road to calculate this interval for the amber indication. This formula will be used to measure the distance beyond which a driver could easily stop for a pedestrian by multiplying the time by the speed limit, and a landmark will be placed at this distance on each side of each crosswalk by placing a traffic cone near the curb or edge of the road. Be sure the cone does not create an obstacle for pedestrians on the sidewalk. Anyone inside the calculated distance may not have sufficient distance to safely stop for a pedestrian in the crosswalk and therefore is not scored as not yielding (though the can still be scored as yielding). Anyone who has not yet passed the traffic cone is assumed to have sufficient distance to safely stop before the crosswalk.

The formula for the calculating the dilemma zone is **$Y = t + V/(2a+2Ag)$** where:

- **Y**= Yellow clearance interval in seconds
- **t**= reaction time (use 1 second)
- **V**= approach speed in ft/sec (use posted speed limit)
- **a**= deceleration rate of a vehicle (use 10 ft/sec/sec)

[1] http://homepages.wmich.edu/~s9crowle/SCOPE%20OF%20WORK-2.pdf

A= Acceleration due to gravity (use 32.2 ft/sec/sec)
g= percent grade in decimal form (+for upgrade,**-** for downgrade; this is unknown but considered to be 0).

When the data collectors arrive at a site, they will measure the dilemma zone from the outside edge of the crosswalk line closest to approaching traffic and then mark the end of the zone with a traffic cone. Data collectors will check to make sure that the cone is visible to them from the marked crosswalk. Depending on the posted speed limit, the dilemma zone will be:

- 40 MPH Posted speed: 231 ft
- 35 MPH Posted speed: 183 ft
- 30 MPH Posted speed: 141 ft
- 25 MPH Posted speed: 104 ft
- 20 MPH Posted speed: 72 ft

If the speed is not posted, the data collectors will use the dilemma zone for a 35MPH speed limit. No sites are posted at higher than 35 MPH. However, if you feel that traffic is traveling at significantly higher speeds than the posted speed limit, then use caution and use the 40MPH dilemma zone distance (231 ft). Note the dilemma zone distance used on the data collection form at every visit.

Observer Positioning on Site

Two people will collect data at each site. One will serve as the person staging pedestrian crossings while the other will record all behavioral measures. The recorder will try to set up in a location with a clear view of traffic in both directions but far enough away from the crossing to not raise the attention of passing traffic or pedestrians. The person staging crossings will stand away from the crossing (so as to not display intent to cross) until the conditions are right to follow the staged crossing procedure below.

Staged Crossing Procedure for Uncontrolled Crosswalks

The pedestrian protocols used to collect motorist yielding data will be consistently followed to ensure a standard and safe crossing procedure at uncontrolled crosswalks. These protocols have been selected to provide a standard way of crossing that is compliant with the uniform vehicle code and to ensure the safety of the pedestrian crossing the street. The following protocol will be employed at uncontrolled crosswalks (marked crosswalks that are not controlled by a traffic signals or stop sign). This protocol has been employed in other studies to measured motor vehicle-pedestrian conflicts (a crash surrogate measure) and has not been associated with conflicts.

1. Step with one foot into the crosswalk when an approaching vehicle is **just beyond** the marked dilemma zone (the dilemma zone is the measured distance for the vehicle speed limit and road grade, which ensures a safe stopping distance for vehicles traveling at the posted speed). Make sure that all traffic coming from the opposite direction is beyond the traffic cone. Observer should make note of opposite side traffic location so as to score correctly. If there is on-street parking or a bicycle lane it will be necessary to walk to and stop at the lane line to view approaching traffic and so drivers of approaching vehicles can see the pedestrian. Pedestrians shall not cross into the travel lane until the driver significantly slows or stops his or her vehicle to allow the pedestrian to safely cross.
2. If the vehicle makes no attempt to stop, do not proceed to cross and score the vehicle as not yielding. Also, score subsequent vehicles that do not stop as not yielding.
3. On multilane roads, if the vehicle clearly begins to yield and the next lane is free, begin crossing. **Always stop at the lane line for the second travel lane and make sure the next lane is clear**

before proceeding. Score the vehicle that slowed or stopped as yielding. Do not score any vehicles traveling behind the yielding vehicle as they were forced to yield.

4. If a vehicle in the second lane makes no attempt to slow and stop, let it pass and score it as not yielding.
5. If the vehicle yields or there is a large gap in traffic, proceed to the median (if applicable) or finish crossing to the other side of the street to begin to measure yielding for the other direction of traffic. Do not create a situation where you will be trapped in the centerline if there is no median—be sure you will be able to cross the full street safely.
6. If a vehicle yields that is **inside** the marked dilemma zone, score the driver as yielding, but if they do not yield, do not score them at all**. All vehicles that have not yet entered the marked dilemma zone when you are halfway across the 2nd travel lane that do not slow or stop to allow you to cross should be scored as not yielding.**

These procedures will be carefully adhered to in order to gather enough data to calculate motorist yielding rates at each location. A minimum of 25 staged crossings will be performed at each site. If possible, data collectors will also gather data on any natural crossings observed during the 2-hour time period. When staged crossings are completed, the staged pedestrian can begin collecting data on natural crossings at the same time as the other recorder gathers data. The data collectors should note on the forms when they are both collecting data at the same time, and should avoid comparing decisions or talking about the data during this time—the data collection should be independent.

Measures

The following measures will be recorded using the data collection shown in Appendix A.

Driver yielding to pedestrians

Observers will score the percentage of motorists yielding and not yielding to pedestrians. A motorist will be scored as yielding if he or she stops or slows to allow the pedestrian to cross. A motorist will be scored as not yielding if he or she passes in front of the pedestrian but would have been able to stop when the pedestrian arrived at the crosswalk. We will use the formula used by traffic engineers to determine whether a driver could have safely stopped at a traffic signal that was presented under the calculation of dilemma zone to determine whether the driver could have stopped for a pedestrian. Motorists who have passed this landmark when a pedestrian enters the crosswalk can be scored as yielding to pedestrians but not as failing to yield, because they have passed a point in which there was sufficient time to yield. Motorists beyond the landmark when the pedestrian entered the crosswalk can be scored as yielding or not yielding because they have sufficient distance to safely stop. When the pedestrian first starts to cross, only drivers in the first half of the roadway will be scored for yielding. Once the pedestrian approaches within a half lane of the median, the yielding behaviors of motorists in the remaining lane(s) will be scored.

Conflicts between motorists and pedestrians

A conflict between a motorist and a pedestrian will be scored whenever a motorist suddenly stops or swerves to avoid striking a pedestrian or whenever a pedestrian jumps, runs, or suddenly steps or lunges backward to avoid being struck by a vehicle. Because pedestrians will be following the safe crossing protocol these types of incidents should be rare events. The may be more likely to occur when observing natural crossings.

Driver passed or attempted to pass stopped vehicle

A driver is recorded as passing a stopped vehicle if they passed a vehicle that was yielding to the pedestrian. A driver is recorded as attempting to pass a stopped vehicle if they did not yield until after they were alongside, or past, a yielding vehicle and hence then seeing the pedestrian, or if the driver behind a yielding vehicle changed lanes to go around but then yielded.

Car behind yielding car performs rapid deceleration (Hard Brake)
A car is recorded as performing rapid deceleration if they were behind a yielding car and the front-end of the car was observed taking a sudden movement to the ground.

Car braking closely to the crosswalk (Close Stop)
A car is recorded as braking closely to the crosswalk if they brake within 10 feet of the crosswalk. The data collection team should measure off the distance 10 feet from the edge of the crosswalk closest to approaching traffic and place a marker (tape, a rock, sidewalk chalk, etc.) there to help them gauge if cars stopped or yielded closer than this distance.

Pedestrian trapped at median or centerline
A "trapped" situation may occur if a pedestrian makes it to the center of the road but vehicles coming from the other side do not yield, leaving the pedestrian stranded in the median or at the centerline. A centerline trapping should not occur with staged crossings, but could be observed in natural crossings. A median trapping situation will not be applicable unless a median is present.

Pedestrian outside the crosswalk
For natural observations, record any instances where a pedestrian walks more than 10 feet outside either edge of the crosswalk.

Entering Recorded Data

Once data has been collected, data will need to be transferred from the paper forms into raw and aggregate tables using Microsoft Excel. Upon returning to the office with completed data forms, follow these steps to ensure data is entered accurately and consistently.

1. Scan completed data forms into PDF format
2. Open the Raw Data Excel File and use a copy of the Template worksheet to enter each data form. Be sure to transfer all fields from the paper form into the template, including any relevant notes. Once complete, rename the worksheet using the following structure:

   First Letter of City-Major Road Name-Month Number-Day Number

3. Once all Raw Data has been entered, transfer the data from each new worksheet into the Aggregate Data Excel File. For each visit, there will be one row for Staged Crossings and one row for Natural Crossings. Transfer the number of vehicles yielding and not yielding, as well as the date, observer name, pedestrian name, and all other conflicts observed.
4. Once all data entry is complete, review both the Raw Data and Aggregate Data tables against the original forms to ensure consistency. When all fields have been checked, email scanned forms, Raw Data, and Aggregate Data tables to Dan Gelinne (gelinne@hsrc.unc.edu).

Inter-observer Agreement

A subset of the data collected will be used to calculate inter-observer agreement and procedural integrity. A measure of inter-observer agreement will be computed by dividing the number of times both observers agreed on the occurrence of each driver behavior by the number of times they agreed plus the number of times they disagreed on its occurrence. Inter-observer agreement will also be computed for the treatment integrity measure described below. A measure of inter-observer agreement will be computed at least once at each site, using the data collected by both recorders of natural crossings, after all staged crossings have been performed. For this reason, during the recordings of natural events, data collectors should not discuss the data they are collecting.

Description of Roadway Settings

Each crosswalk setting has already be described in terms of number of lanes, stop control, speed, intersection configuration, crossing type, and other surrounding factors such as significant landmarks, parked cars and bus stops. At the bottom of the tally sheet, data collectors will record any unusual circumstances that may have impacted data collection or the behaviors observed, including construction, congestion, events, obstructions, law enforcement or crossing guards present, etc.

General Safety

Data collectors will be standing near roadway intersections to collect data. Use caution traveling to the locations, including crossing roadways near the sites. Follow traffic laws at all times. Maintain a constant awareness of your surroundings, including traffic conditions and social situations, and ensure that data collection does not interfere with your attention to safety. If you feel unsafe, uncomfortable, or threatened at any time, stop data collection and move to a safer location.

13. APPENDIX F: FIELD DATA COLLECTION FORMS FROM YEAR 1 AND YEAR 2

Year 1 Data Collection Form

Intersection or midblock crossing name:____

Weather: _____________Date: ______________ Observer name: _________________________

Data collection start time: ____________end time: _________________DZ measure:_________

Event	Yield	NO Yield	Conflict	Attempted to Pass	Hard Brake	Close Stop	Trapped Ped	No X-walk use	Notes (number of vehicles, distraction, etc.)
Staged Pedestrian Crossings: NAME OF STAGED PEDESTRIAN____________________________									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
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14									
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16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
Natural Pedestrian Crossings									
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									

Year 1 Study Information Sheet

July 3, 2012

Data collectors, working on behalf of the UNC-Chapel Hill Highway Safety Research Center, are conducting studies of driver and pedestrian behavior at marked crosswalk throughout the Triangle area as a part of a project to evaluate a campaign (funded by the National Highway Traffic Safety Administration and the North Carolina Department of Transportation) to improve pedestrian safety. No personal or vehicle identifying information is being collected. Data collection will occur on weekdays throughout the months of July 2012 through February 2013. Locations for data collection include:

- In Durham:
    - University @ Chapel
    - Gregson Near Main (at Brightleaf)
    - Anderson @ Yearby
    - Lamond @ Gregson
    - Fayetteville @ Peekoe
    - Tobacco Trail Near Riddle
- In Raleigh:
    - Wilmington between Hargett and Martin
    - Wilmington near New Bern (by Capitol)
    - Blount Street between Martin and Hargett
    - Martin @ State
    - Martin @ Bloodworth
    - South near Fayetteville (between Wilmington and Salsbury)

If you have any questions about the data collection procedures or how the data will be used, please contact the project's Principle Investigator: Laura Sandt at sandt@hsrc.unc.edu or 919-962-2358.

Year 2 Data Collection Form

Intersection or midblock crossing name:____
Weather: ______________Date: _______________ Observer name: __________________________
Data collection start time: _____________end time: __________________DZ measure:__________

Event	Yield	NO Yield	Conflict	Attempted to Pass	Hard Brake	Close Stop	Trapped Ped	No X-walk use	Ped device use	Notes (police car involvement, context, etc.)
Staged Pedestrian Crossings: NAME OF STAGED PEDESTRIAN______________________________										
1										
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43										

Event	Yield	NO Yield	Conflict	Attempted to Pass	Hard Brake	Close Stop	Trapped Ped	No X-walk use	Ped device use	Notes (police car involvement, context, etc.)
44										
45										
46										
47										
48										
49										
50										
Natural Pedestrian Crossings										
1										
2										
3										
4										
5										
6										
7										
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Other notes (construction, events, weather, traffic conditions, etc.):

Year 2 Study Information Sheet

July 30, 2013

Data collectors, working on behalf of the UNC-Chapel Hill Highway Safety Research Center, are conducting studies of driver and pedestrian behavior at marked crosswalks throughout the Triangle area as a part of a project to evaluate a campaign (funded by the National Highway Traffic Safety Administration and the North Carolina Department of Transportation) to improve pedestrian safety. Data on bicyclists will also be collected on local Triangle trails and streets. No personal or vehicle identifying information is being collected. Data collection will occur on weekdays throughout the months of August 2013 through February 2013. Locations for data collection include:

- In Durham:
    - University @ Chapel
    - Gregson Near Main (at Brightleaf)
    - Anderson @ Yearby
    - Lamond @ Gregson
    - Fayetteville @ Peekoe
    - Tobacco Trail Near Riddle
    - Ninth St Corridor
- In Raleigh:
    - Wilmington between Hargett and Martin
    - Wilmington near New Bern (by Capitol)
    - Blount Street between Martin and Hargett
    - South near Fayetteville (between Wilmington and Salsbury)
    - 1603 Hillsborough St (in front of the YMCA)
- In Chapel Hill/Carrboro:
    - 730 MLK Jr, Blvd (by Bolin Creek Center)
    - Pittsboro St. @ State Employees Credit Union
    - Franklin St @ Granville Towers
    - Greensboro between Main St and Weaver St
    - Hillsborough Rd @ James St

An IRB application was submitted and reviewed by the Office of Human Research and Ethics and received a notice of IRB Exemption (study # 13-2567). Efforts are in place to protect all human subjects and field data collectors involved in this research. If you have any questions about the data collection procedures or how the data will be used, please contact the project's Principle Investigator: Laura Sandt at sandt@hsrc.unc.edu or 919-962-2358.