Roadway Characteristics and Pediatric Pedestrian Injury

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Introduction

Significance of Pediatric Pedestrian Injuries

In the 1990's cars struck approximately 50,000 children in the U.S. each year, killing 1,800 (1). These rates have declined to approximately 39,000 injuries and 630 fatalities yearly (2). The case fatality rate has similarly declined from 3.6% to 1.6%. Case-fatality, though, varies from approximately 1% for the oldest children, to 9% for the youngest, and compared to the 94% of motor vehicle occupants that escape crashes unscathed, only 1% of pedestrians walk away uninjured (1).

Although there has been a 43% decline in pedestrian death rates since 1975 (3), child pedestrian injury continues to rank among the most serious childhood diseases. In New Zealand, pedestrian injuries kill twice as many children as leukemia and 5 times as many as all infectious diseases combined (4) .

Morbidity statistics are more difficult to come by, but in 1996 there were 163,000 emergency department visits for pedestrian injuries for all ages (5). In areas of New York City from 1989 to 1995, an estimated 127/100,000 pediatric population suffered severe pedestrian injury (6). Pedestrian injuries account for 5% of all pediatric trauma admissions to US hospitals (7).

Research Gaps

What at first appears as a relatively straightforward mechanism of injury, the exposure of a child to traffic, rapidly become quite complex. Behavioral, social, cultural, ethnic, physical and environmental factors all play a role. Interaction between variables is likely, for example the risk posed by the physical environment of a driveway may interact with the behavioral risk posed by young age. To describe causal associations between the variables it is also necessary to rule out confounding factors, for example an increased risk posed by clearly marked walkways may be due, in part, to the location of such roadways in highly trafficked areas.

In general, a lower socio-economic status translates into increased risk (8-10). In Northern Manhattan, New York City, children in low-income neighborhoods have twice the risk of pedestrian injury relative to those better off (11). Yet it is not entirely clear what it is about SES that mediates this risk. In the U.S, being a member of a minority or non-white group clearly increases risk (8, 10). One study of race attempted to control for income by using insurance payment class and reported an odds ratio of 2.59 (9). A New Zealand study found a 3 times greater injury admission rate for indigenous children vs. children of European descent (7). It has been hypothesized that minority-group status and low SES lead to increased exposure through increased walking (12, 13), or that such stressors as family illness and maternal pre-occupation somehow mediate increased risk (14, 15). In the terminology of Link and Phelan, low SES puts children at risk of the more proximal individual risks that have been identified (16).

The Built Environment and Pediatric Pedestrian Injury

The built environment plays a crucial role in the risk of child pedestrian injury and is closely related to the social, cultural and economic status of the community (7-11). Child pedestrian injury is primarily an urban phenomenon (17). Up to 75% of child pedestrian injuries occur in an urban setting (18). Rates are proportionate to population density, with urban areas accounting for 2/3 of all US pedestrian deaths (19) . In these areas pedestrian injuries outnumber occupant injuries (6). Milwaukee, with 14% of Wisconsin's population, accounts for 35% of that state's pedestrian injuries (20). In New York City, pedestrian deaths have outnumbered occupant deaths since 1910, and the first recorded motor-vehicle crash fatalities in both the United Kingdom and in the United States (which occurred in London and New York City respectively) were both pedestrians (19).

Some built environmental risk has been attributed to multi-family dwellings (21), some to a lack of playgrounds (6, 14, 21), some to the presence of major roadways (17, 22), and some to increased traffic volume (6, 23). The presence of curbside parking is also associated with an increased risk of injury (4); this may be related to the so-called mid-block "dart and dash" type of injury (18). The presence of such road attractions as ice cream vendors has also been found to increase the risk of an injury occurring (18, 20).

Changes to the built environment have been called a “logical but often overlooked” area of injury control though they are often “the most successful interventions” (24). Modifications to the built environment that may increase pediatric pedestrian safety include separating play areas from roadways, improved visibility at intersections, conspicuous stop signs, enhanced pavement markings and improved lighting.

In this paper, we systematically reviewed the literature on built environment and pediatric pedestrian injury risk. We conducted a meta-analysis to synthesize the evidence on the effectiveness of interventions to the built environment to prevent pediatric pedestrian injury. We attempted to answer three questions: 1) How strong is the association between the built environment, particularly roadway environment, and the risk of pediatric pedestrian injury? 2) Does the strength of any demonstrated association vary by age group? 3) Does the strength of any association vary by study type or geographic area in which the study was conducted?

To answer these questions we used Bayesian meta-analytic techniques which allowed us to determine how widely study results varied, calculate the direct probability of overall mean effect size, estimate how likely is it that future studies would demonstrate an association similar to that found in this meta-analysis, and assess how sensitive the results are to prior assumptions regarding risk.

Methods

We searched PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Health and Psychosocial Instruments, Proquest Digital Dissertations, PapersFirst, Allied and Complementary Medicine (AMED), Evidence Based Medicine (EBM) Reviews, the ACP Journal Club, the Database of Abstracts of Reviews of Effects (DARE) and the Cochrane Database of Systematic Reviews for studies related to built environment and child pedestrian injuries. We used the search terms: `built environment', `child*', `injur*', `pedestrian', `walk*' (where * represents a wildcard character) alone and in combination.

Studies were eligible for analysis if they presented results in terms of proportions or prevalence, odds ratios of dichotomous variables, means with standard deviations, p-values, t-tests, F-statistics, and chi squares, or with data that could be translated into one of those terms. Where possible, analyses were based on extraction of raw data from tables and charts.

Articles were uploaded into Endnote 9.0. (25) We used the search feature in Endnote to remove duplicate entries, then read the titles of all remaining entries to exclude studies not related to pediatric pedestrian injury. We read the abstracts of the entries to remove studies without references to the built environment. To identify quantitative epidemiologic studies, we conducted full-text electronic searches of the remaining entries the terms: `study, investigation, incidence, prevalence, proportion, effect, random*, population, research, cross-sectional, ecologic, and epidem*'. The references of remaining articles were visually inspected to identify additional articles.

Full-text versions of articles were reviewed by the first author (CD). Articles presenting additional or repeated analyses of previously published data were excluded to maintain the independence of studies entered into the analysis. Remaining studies were coded for the following variables: whether the study was based on an intervention to the built environment (e.g. road reconstruction or calming, signage) vs. observational studies; the built environmental factor studied (e.g. residential vs recreational or commercial buildings, curbside parking, driveways, nearby schools); the outcome or dependent variable studied (fatality, injury, driver giving way to pedestrian); the geographic location of the study (Europe, North America, Oceana and Australia, Africa, Asia, South America); type of study (case-control, case-series, pre-post) and the age group (pediatric vs. all ages). We grouped outcomes under three main categories: social built environment like nearby schools and parks, roadway built environment like overpasses and number of lanes, and vehicle-related factors such as parking availability.

We converted results to odds ratios using reported results or based on abstracted results. We abstracted measures of effect and their 95% confidence limits for each study. Each study result was entered with the risk of injury or fatality as the outcome of interest. So for intervention studies, data were converted from preventive measure to measures of increased risk.

We used Bayesian analyses where our two main sources of information about the synthesized effect size (θ) are our prior beliefs or the prior distribution of the parameter (Pr[θ]) and the likelihood of observing the data given that prior belief or distribution (Pr[y|θ]). The result of combining the prior distribution and the likelihood is called the posterior distribution and follows Bayes' Theorem:

$$Pr[\theta|y] \propto Pr[y|\theta] * Pr[\theta],$$

Our prior distribution is essentially what we believe the synthesized effect size θ is and how we think it might vary if we had no data upon which to base our judgments. The likelihood informs about θ via the data itself. When we have a lot of data, the likelihood predominates, and our results will essentially be the maximum likelihood or traditional estimate. When we have less data, the prior has greater influence. We can also use the results of Bayesian analysis of the posterior distribution of theta given the data, to inform a predictive distribution of possible data values given our new knowledge about theta. This is termed the posterior predictive distribution. Of note, the posterior predictive distribution is invariably less precise than the posterior distribution on which it is based because it incorporates both the uncertainty of the parameter estimate and a data value based on the distribution of that data given a particular parameter estimate.

We entered data into R for descriptive analyses. We then entered data into Comprehensive Meta Analysis version 2. (26) to calculate effect sizes and variances for each study finding. The heterogeneity of the mean effect size for an outcome across studies was tested with a Q statistic. If Q is larger than the critical value of Chi square statistic with k-1 degrees of freedom, where k is the number of effect sizes, we rejected a null hypothesis of homogeneity across effect sizes. We then entered the effect sizes for each finding into the R statistical computing program (27) and WinBUGS (28) and calculated overall effects with a Bayesian random effects model as described below.

For the meta-analysis, we modeled the outcomes as logits of the abstracted odds ratios from each study. For the fixed effect model, the logits were assumed to be normally distributed with a mean of 0 and a wide variance of 10^5, which allowed the value of the logits to vary from -619.36 to 619.36. Assuming that it might be unreasonable to assume that all the studies were estimating exactly the same treatment effect, and that there was likely more statistical heterogeneity or difference between studies that might reasonably be attributed solely to random error, we conducted a random effects model which included an additional variance component for between studies variation. This random effects term had it's own mean ɗ and variance τ^2. We placed a vague normal prior with mean 0 and variance 10^5 on ɗ and a uniform (0, 10) prior on τ^2.

Most reasonably realistic problems framed in this way do not have a simple or closed solution amenable to maximum likelihood estimates, so we used a simulation approach to solve for the parameter estimates. The WinBUGS package, developed in UK, allows for a Monte Carol Markov Chain simulation approach by choosing samples using either Gibb's (for which it's named) or Metropolis Hasting algorithms. Because this is a simulation-based approach, we repeat many draws or iterations and evaluate whether the chain of sample values converges to a stable distribution that is assumed be the posterior distribution in which we are interested.

We entered our models into WinBUGS and ran two 20,000 Markov Chain Monte Carlo iterations each starting with different and dispersed initial values for the model. We based our results on the final 10,000 iterations, and assessed whether the chain of values had converged to a stable posterior distribution by monitoring and assessing a graph of the chain as well as by calculating the Brooks Gellman and Rubin statistic, a tool within the WinBUGS program for this purpose.

We synthesized the results of all studies related to built roadway environment and compared that effect size against studies for non-roadway related built environment. To assess potential bias or confounding due to age, study type and setting, we additionally synthesized estimates stratified by whether the studies were restricted solely to pediatric populations vs. those that included adults, for intervention studies vs. observational studies, and for studies set in high-income vs.

lower-income economies. Because of these subgroup analyses, the total number of studies differed from meta-analysis to meta-analysis.

The results are mean values of the posterior distributions and their 95% credible intervals (Cr I). Where appropriate, we exponentiated the logits which were used in the meta-analyses to present results in their original scale. Plots and graphs were created within the R statistical computing package.(27) The study protocol was approved by the (removed for peer review) Institutional Review Board and complies with the Public Health Code of Ethics.

Results

Our initial electronic search returned 186 studies that potentially met entry criteria. Of these, 72 studies (39%) were excluded as not relevant or duplicates based on a review of their titles and abstracts. A review of the references of the remaining 114 studies identified an additional 14 studies for a total of 128 studies for full-text review. Twenty-six of the 128 studies (20%) had quantitative results for built environmental factors related to pedestrian injury risk and were chosen for inclusion in the meta analysis. (29-51) (Table 1)

Nineteen studies (73%) were restricted to pediatric populations. Eight studies included both children and adults. The most common study design was case control (11/26=42%). Nine studies (34%) were based on case series and 6 studies (23%) made pre-post comparisons following interventions. Eleven studies were conducted in Europe, 4 studies in North America, 3 studies in Oceana and Australia, 2 studies in Africa, 1 study in Asia and 1 study in South America.

Among the 26 studies, there were 76 discrete outcomes related to the built environment including both fatal and non-fatal injuries (Appendix). The majority (40/76=52%) of the reported results were related to the roadway environment. Nineteen results (25%) were related to the social built environment, and 17 results (22%) were related to the vehicular built environment.

Among the overall 40 results related to built roadway characteristics, 22 independent results had sufficient data to enter into the meta-analysis. Of the 22 roadway results, 13 (60%) were based on pre-post comparisons of roadway interventions. The remaining 9 studies evaluating existing roadway conditions using case-control or case-series designs. Seven of the 13 intervention studies evaluated road reconstruction, including overpasses, 4 evaluated road closures, narrowing and speed bumps, 1 study involved signage changes, and 1 study referenced "traffic calming" not otherwise specified. Ten of the 22 study results were restricted to pediatric populations; 12 looked at all age groups.

A random effects model synthesizing the odds ratios for the 22 results for the association of built roadway characteristics and risk of pedestrian injury mixed well and converged to a stationary posterior distribution as evidenced by plot tracings and diagnostic tests. Both the posterior and posterior predictive distributions appeared to be normally distributed around a single mean estimate.

Point estimates for the odds ratio for the association of roadway characteristics with risk of injury or death ranged from 0.6 to 10.1. The synthesized effect estimate for all 22 studies was an odds ratio of 1.6 (95% CrI 1.2, 2.1). (Figure 1). There was an 80% probability that any future study of 1000 individuals would demonstrate an association between roadway characteristics and risk of injury or death.   The funnel plot for these 22 study results is approximately symmetric about the synthesized estimate. (Figure 2)

When stratified by study type, the synthesized estimate for observational studies of built roadway characteristics was OR=2.2 (95% CrI 1.2, 2.4), compared to a synthesized estimate for pre-post intervention studies which returned an OR=1.4 (95% CrI 1.0, 1.8). When restricted to the 15 of the 22 roadway studies that were conducted in Western industrialized nations, the synthesized odds ratio was 1.5 (95% Cr I 1.1, 2.0). For the 7 studies conducted in non-Western or developing nations, the synthesized point estimate was OR=2.0 (95% Cr I 0.9, 4.9)

Of the 10 f the 22 roadway study results looking exclusively at pediatric populations, the synthesized effect estimate was 2.5 (95% Cr I 1.8, 3.2). The probability of a new study showing an association between built roadway and pediatric pedestrian injury was nearly 100%. (Figure 3)

Of the 36 results not related to the built roadway environment, 9 (25%) independent study results had sufficient data for inclusion in a meta-analysis. Four of the results were related to the social environment. Of these, two were related to play areas or playgrounds, one was related to a nearby school, one to street vendors, one to alcohol outlets and one to retail establishments. The 5 studies related to vehicle factors were concerned with vehicle density.

The synthesized effect estimate for these 9 study results which addressed built environment not directly related to roadway characteristics was OR=2.1 (95% Cr I

1.2, 3.4). (Figure 4) Again, the density plot indicated that the synthesized effect size was measuring a single normally distributed estimate. There was a 90% probability that any future study would demonstrate an effect in the same direction.

Discussion

Pedestrian crashes are complicated and complex events. There are many variables at play such as driver and pedestrian behavior, vehicle engineering and geometry, weather and lighting conditions, and traffic laws. The variables themselves as well as drivers and pedestrians are diverse, interrelated and adapt to each other resulting in outcomes that cannot easily be predicted and are sometimes completely unexpected.

In this meta analysis, rather than attempt to control for potential confounders and test for interaction variables with meta-regression techniques, we chose to use stratified and restricted analysis to examine the role of the different variables. In this way we may better appreciate that while the overall 60% effect of built roadway on pedestrian injury risk is in many respects rather modest, it varies in important ways. Notably, the risks to children posed by built roadway characteristics are more than double that seen when all age groups are combined.

A useful epidemiological approach to interpreting these results is through attributable risk. In this approach, the overall community risk that one may attribute to the built roadway environment will depend on the prevalence of dangerous roads or roadway features in that community. So, for example, if 10% of roads in a particular area are dangerous to pedestrians, then the attributable risk for built roadway would be about 6%[1]. If, though, one were primarily concerned with risk to children, the attributable risk climbs to 33%.

While we found that, over all, characteristics not directly attributable to the built roadway may have twice as much influence as road way characteristics, this result must be viewed with caution. Those variables that we categorized as "non-roadway" are likely to have some relationship to roadway characteristics. And, as noted previously, many risk factors interact with each other. So, for example, vehicle density is affected by number of lanes and nearby attractions like retail establishments and in turn will impact average vehicle speed in an area. It has also become increasingly clear that in many areas of the world, children are simply walking and playing in the streets less (52), which also has implications for the interpretation of these results.

Against the complexity of pediatric pedestrian injury risk, built environment characteristics, particularly roadway characteristics, offer attractive and apparently straightforward opportunities for interventions. The results of this meta-analysis indicate that this enthusiasm may be well placed. And, while, built roadway interventions are expensive, this review indicates that important gains may be made by relatively simple approaches like speed humps, and changing signage.

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[1] The attributable risk (AR), which is calculated using the formula:

$$AR = [p \times (OR - 1)]/[1 + p \times (OR - 1)],$$

where p denotes the prevalence of the exposure variable, and OR is the odds ratio.

We do not, though, in this study, measure which roadway characteristics are most amenable to interventions. Previous studies though have done so and have concluded that adding sidewalks, single-lane roundabouts, refuge islands and increased lighting are the most effective approaches. (53)

The results of this review, while, encouraging for the effectiveness of changes to the built environment on pediatric pedestrian injury risk, should be interpreted with caution. In general, combining studies through meta-analysis increases the power to find significant results and imposes a useful discipline on data synthesis by making the process of combining studies more organized and systematic than in traditional reviews. A Bayesian approach additionally allows us to make explicit what we often do implicitly, i.e. evaluate evidence given our expectations, and permits us to make (cautious) predictions by combining information about the probability distribution of a parameter or effect size with the likelihood of seeing a specific value given the observed data.

This must be balanced against the recognized weaknesses of a meta-analytic approach. It is limited to close-ended quantitative formats and outcomes. Missing on unpublished studies may differ systematically from what is found in the literature. The studies that are combined may differ appreciably and in many important aspects related to type and conduct. And, the statistical summaries may overshadow the more important aspects of appreciating the entire landscape of the extant research.

In conclusion, this review and meta-analysis suggest that even modest interventions to the built roadway environment may result in meaningful reductions in pediatric pedestrian injury risk. By pooling the available evidence, these results may help establish evidence against which to measure interventions to reduce and control pediatric pedestrian injury and fatality.

Tables and Figures

Table 1. Studies included in Meta-Analysis of Built Environment and Risk of Pedestrian Injury.

First Author, year (Reference)	AGE GROUP	GEOGRAPHIC LOCATION	STUDY TYPE
Brison, 1988 (30)	<5	North Am	case series
Mueller, 1990 (21)	< 15 y/o	North Am	case-control
Roberts, 1995 (46)	1-4 y/o	Oceana	case-control
Stevenson, 1995 (49)	1-14 y/o	Australia	case-control
Roberts, 1995(4)	<7	Oceana	case-control
Agran, 1996	< 14	North Am	case-control
Stevenson, 1996 (48)	1-14 y/o	Australia	case-control
Stevenson, 1997 (49)	1-14 y/o	Australia	case-control
Stevenson, 1997(49)	1-14 y/o	Australia	case-control
Lascala, 2000 (38)	all ages	North Am	case series
Wazana, 2000 (51)	<15	North Am	case-series
Mutto, 2002 (43)	all ages	Africa	case-series
Bunn, 2003 (31)	all ages	Europe	pre-post
Morrison, 2004 (42)	all ages	Europe	pre-post
Nakahara, 2004 (44)	5-14 y/o	Asia	case-series
Tester, 2004 (52)	<15	North Am	case-control
Jones, 2005 (37)	4-16 y/o	Europe	pre-post
Lee, 2005 (41)	all ages	North Am	case series
Leden, 2006 (39)	<13	Europe	pre-post
Leden, 2006(40)	all ages	Europe	pre-post
Clifton, 2007 (32)	<15	North Am	case series
Johanson, 2007 (36)	<13	Europe	pre-post
Donroe, 2008 (35)	<19	South Am	case-control
Dissanayake, 2009 (34)	<15	Europe	case series
Damsere, 2010 (33)	all ages	Africa	case series
Shepard, 2010 (48)	<7	Oceana	case-control

Figure 1: Forest Plot, meta-analysis odds ratios for association of built roadway characteristics and risk of pedestrian injury, *all ages*.

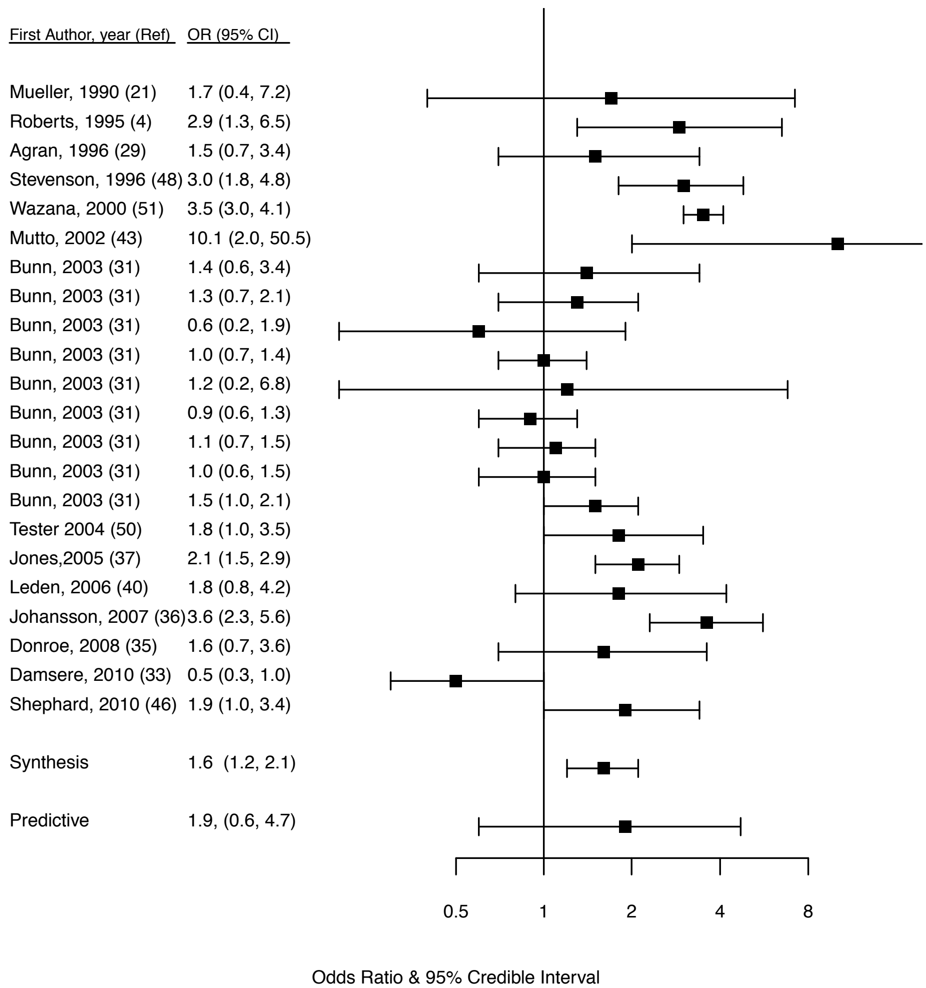


Figure 2: Funnel plot meta-analysis odds ratios for association of built roadway characteristics and risk of pedestrian injury, *all ages*. Vertical dashed line at summary estimate. Asterisks indicate symmetric funnel by reflecting the plot around the summary estimate value.

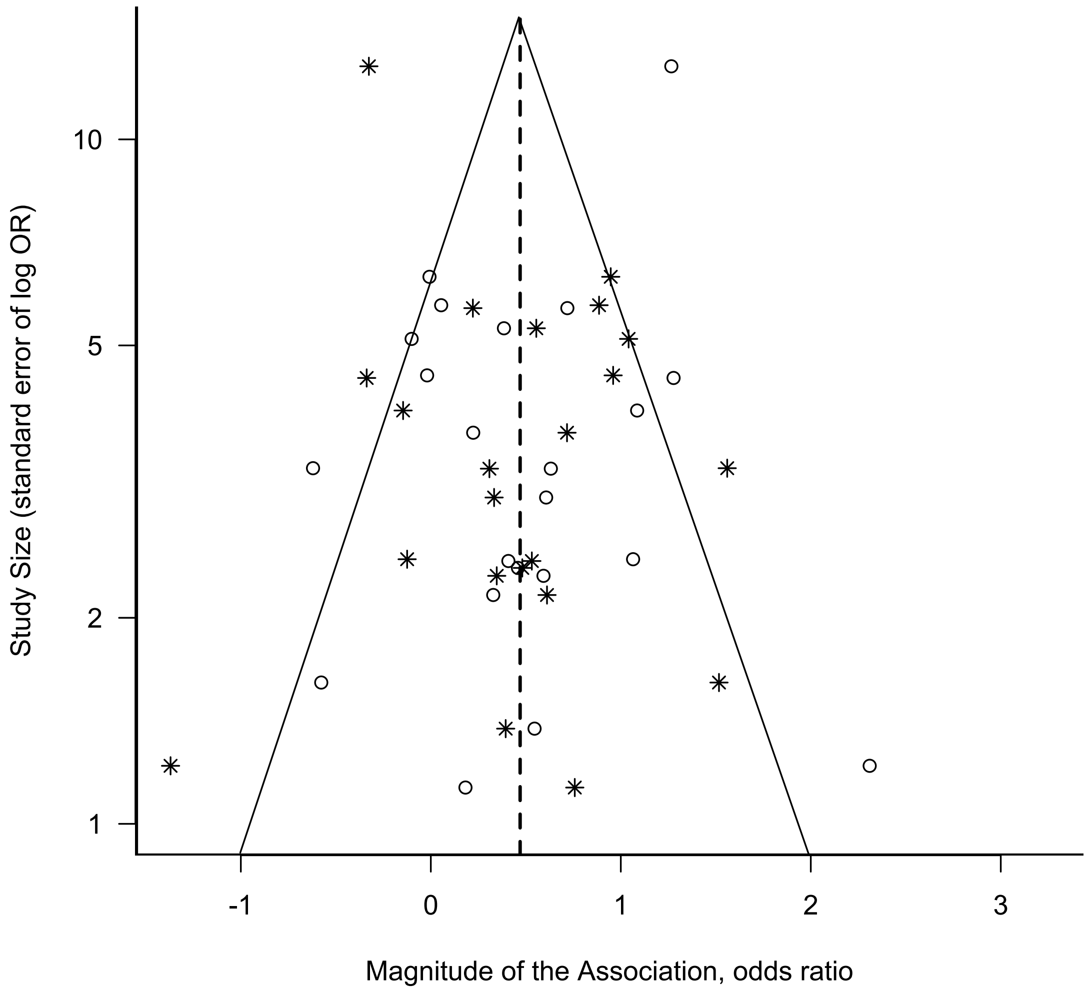


Figure 3. Forest Plot, meta-analysis odds ratios for association of built roadway characteristics and risk of pedestrian injury, *pediatric populations only*.

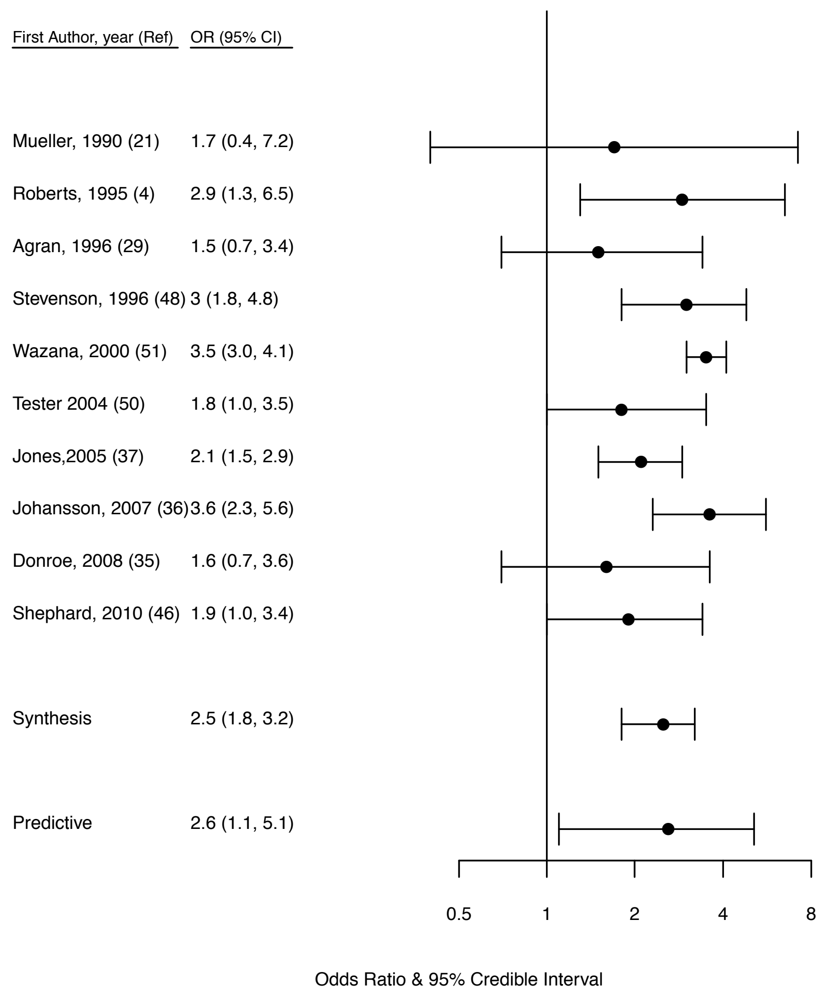
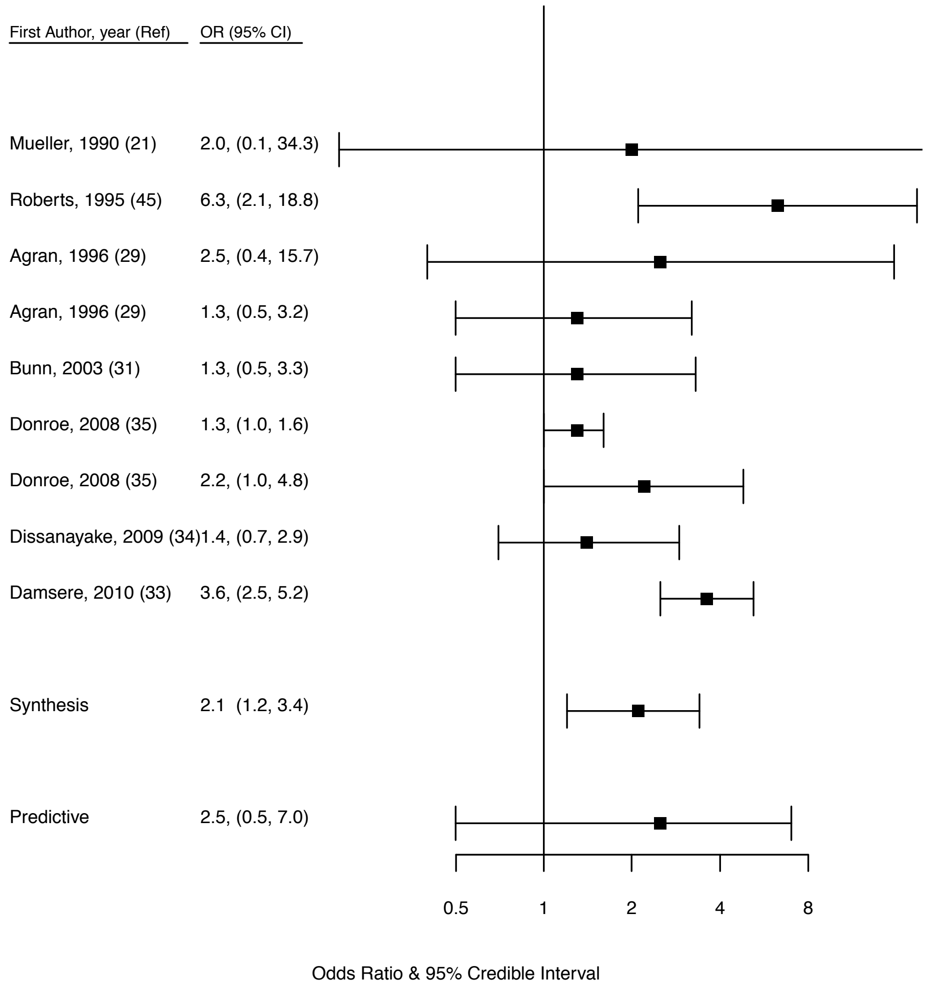


Figure 4: Forest Plot, meta-analysis odds ratios for the association of *non-roadway* related built environment characteristics with risk of pedestrian injury.


First Author, year (Ref)
OR (95% CI)
Mueller, 1990 (21)
2.0, (0.1, 34.3)
Roberts, 1995 (45)
6.3, (2.1, 18.8)
Agran, 1996 (29)
2.5, (0.4, 15.7)
Agran, 1996 (29)
1.3, (0.5, 3.2)
Bunn, 2003 (31)
1.3, (0.5, 3.3)
Donroe, 2008 (35)
1.3, (1.0, 1.6)
Donroe, 2008 (35)
2.2, (1.0, 4.8)
Dissanayake, 2009 (34)
1.4, (0.7, 2.9)
Damsere, 2010 (33)
3.6, (2.5, 5.2)
Synthesis
2.1 (1.2, 3.4)
Predictive
2.5, (0.5, 7.0)
0.5
1
2
4
8
Odds Ratio & 95% Credible Interval

Appendix: 76 Results from 26 Studies of Built Environment and Risk of Pedestrian Injury

Study Result (author, year, (ref)	INTERVENTION	EXPOSURE VARIABLE	OUTCOME VARIABLE	BUILT ENVIRONMENT CATEGORY
agran, 1996(29a)	none	multifamily residence	non-fatal injury	social
agran, 1996(29b)	none	parked vehicles	non-fatal injury	roadway
agran, 19969(29c)	none	number of pedestrians	non-fatal injury	social
agran, 1996(29d)	none	no play area	non-fatal injury	social
agran, 1996(29e)	none	no enclosed play area	non-fatal injury	roadway
agran, 1996(29f)	none	no barrier to street	non-fatal injury	roadway
agran, 1996(29g)	none	mixed vs residential land	non-fatal injury	social
agran, 1996(29h)	none	width roadway	non-fatal injury	roadway
agran, 1996(29i)	none	traffic density	non-fatal injury	vehicle
agran, 1996(29j)	none	vehicle speed	non-fatal injury	vehicle
brison, 1988(30b)	none	driveways	fatality	roadway
brison, 1988(30a)	none	parking lots	fatality	roadway
bunn, 2003(31a)	road narrowing, speed restrictions	vehicle speed	pedestrian crashes	vehicle
bunn, 2003(31b)	road reconstruction	vehicle density	pedestrian crashes	vehicle
bunn, 2003(31c)	street renewal	vehicle density	pedestrian crashes	vehicle
bunn, 2003(31d)	road narrowing	vehicle speed	pedestrian crashes	vehicle
bunn, 2003(31e)	road reconstruction	vehicle speed	pedestrian crashes	vehicle
bunn, 2003(31f)	speed bumps	vehicle speed	pedestrian crashes	vehicle
bunn, 2003(31g)	road reconstruction	vehicle speed	pedestrian crashes	vehicle
bunn, 2003(31h)	signage, crossings	visability	pedestrian crashes	roadway
bunn, 2003(31i)	road closures	vehicle density	pedestrian crashes	vehicle
bunn, 2003(31j)	road closures	vehicle density	pedestrian crashes	vehicle
bunn, 2003(31k)	signage, crossings	visability	pedestrian crashes	roadway
clifton, 2007(32a)	none	nearby playground	school sites of injured children	social
clifton, 2007(32b)	none	traffic density	school sites of injured children	vehicle
clifton, 2007(32c)	none	mixed vs residential land	school sites of injured children	social
damsere, 2010(33a)	none	no median separating traffic	fatal vs non-fatal injury	roadway
damsere, 2010(33b)	none	urbanicity	fatal vs non-fatal injury	social
Damsere, 2010(33c)	none	traffic speed	injury	vehicle

dissanayake, 2009(34b)	none	low density housing	fatal vs non-fatal injuries	social
dissanayake, 2009(34a)	none	secondary retail establishments	fatal vs non-fatal injuries	social
donroe, 2008(35a)	none	vehicle density	serious injury	vehicle
donroe, 2008(35b)	none	vehicle speed	serious injury	vehicle
donroe, 2008(35c)	none	lane markings	serious injury	roadway
donroe, 2008(35d)	none	street vendor density	serious injury	social
donroe, 2008(35e)	none	avenue	serious injury	roadway
donroe, 2008(35f)	none	mixed vs residential land	serious injury	social
donroe, 2008(35g)	none	no speed bump	serious injury	roadway
donroe, 2008(35h)	none	no pedestrian crosswalk	serious injury	roadway
donroe, 2008(35i)	none	no sidewalk	serious injury	roadway
donroe, 2008(35j)	none	>50% curbside parking	serious injury	roadway
donroe, 2008(35k)	none	nearby park	serious injury	social
johansson, 2007(36)	road reconstruction	lack of marked crosswalk	driver giving way to pedestrian	roadway
jones,2005(37)	traffic calming	traffic calming	injury	roadway
lascala, 2000(38)	none	nearby alcohol outlets	fatal and nonfatal injury	social
leden, 2006(39)	marked crosswalks	lack of marked crosswalk	driver giving way to pedestrian	roadway
leden, 2006(40)	road reconstruction	traffic calming	traffic injuries	roadway
lee, 2005(41)	none	traffic control present	fatal and nonfatal	roadway
morrison, 2004(42)	road reconstruction	traffic calming	self-reported perception of road safety	roadway
mueller, 1990(21a)	none	apartment residence	fatal and nonfatal injury	social
mueller, 1990(21b)	none	no play area	fatal and nonfatal injury	social
mueller, 1990(21c)	none	no fence yard	fatal and nonfatal injury	social
mueller, 1990(21d)	none	>2 lanes	fatal and nonfatal injury	roadway
mueller, 1990(21e)	none	>50% curbside parking	fatal and nonfatal injury	roadway
mueller, 1990(21f)	none	no sidewalk	fatal and nonfatal injury	roadway
mueller, 1990(21g)	none	no playground	fatal and nonfatal injury	social
mueller, 1990(21h)	none	nearby school	fatal and nonfatal injury	social
mueller, 1990(21i)	none	marked crosswalk	fatal and nonfatal injury	roadway
mutto, 2002(44)	overpass construction	overpass	fatal vs non-fatal injuries	roadway
nakahara, 2004(45a)	construction	public parks	fatality	social
nakahara, 2004(45c)	construction	paved local roads	fatality	roadway
nakahara, 2004(45b)	construction	pedestrian crossings	fatality	roadway
roberts, 1995(45)	none	traffic volume	injury	vehicle
roberts, 1995(4)	none	curbside parking	injury	roadway
shephard, 2010(46a)	none	driveway length > 12 m	emergency department visit for injury	roadway
shephard, 2010(46b)	none	driveway exits onto local road	emergency department visit for injury	roadway
shephard, 2010(46c)	none	driveway exits onto cul de sac	emergency department visit for injury	roadway
shephard, 2010(46d)	none	more parking areas on property	emergency department visit for injury	roadway

shephard, 2010(46e)	none	local playground, school or shop	emergency department visit for injury	roadway
shephard, 2010(46f)	none	driveway curved	emergency department visit for injury	roadway
stevenson, 1995(49)	none	no footppaths	injury	roadway
stevenson, 1996(48)	none	view obstructed	injury	roadway
stevenson, 1997(47a)	none	view obstructed	injury	roadway
stevenson, 1997(47b)	none	traffic volume	injury	vehicle
tester 2004(50)	none	speed bumps	injury	roadway
wazana, 2000(51)	none	one-way vs two-way streets	injury	roadway

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