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Physical environmental roadway interventions and injury and death for vulnerable road users: a natural experiment in New York City

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Abstract

Introduction: This study examined the effectiveness of three physical environmental roadway interventions (enhanced crossings, speed humps, and turn traffic calming) in preventing crashes involving pedestrian and cyclist injury and mortality in New York City.

Methods: We examined crashes that occurred within a 100-foot radius of intervention and control sites from 2015 to 2019. We used a staggered difference-in-difference design to estimate the association between each intervention type and pedestrian and cyclist crash outcomes.

Results: Estimates for enhanced crossings and speed humps included the possibility of no association with crashes, but estimates for turn traffic calming interventions showed reduced odds of crashes involving pedestrian injury by 16% (OR 0.84, 95% CI 0.74 to 0.95) and crashes involving pedestrian fatality by 80% (OR 0.20, 95% CI 0.08 to 0.47). When stratifying by street segment length as a proxy for areas with high speeding risk, turn traffic calming treatments appeared to be most effective at intersections connected to long street segments.

Discussion: Turn traffic calming may substantially reduce crash risks for pedestrians. Municipalities can prioritise this physical environmental intervention, especially at turns near long street segments, as a low-cost intervention with substantial public health impact.

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INTRODUCTION

Motor vehicle collisions pose a major yet preventable risk to public health, particularly among vulnerable road users (eg, pedestrians and cyclists). In 2021, 7388 pedestrians and 966 cyclists were killed, and 60 577 pedestrians and 41 615 cyclists were injured in traffic crashes in the USA.¹ The risk posed to vulnerable road users is especially salient in New York City (NYC), a dense urban environment in which many individuals walk or bike as their main form of transportation.² Since 2014, NYC has invested in a variety of physical environmental roadway interventions as part of its Vision Zero initiative, a programme aimed at eliminating deaths and serious injuries from motor vehicle collisions.^{3 4} Many of the interventions implemented in NYC, such as pedestrian islands and curb extensions, are well-supported by research⁵⁻⁸ while others have little to no published evidence. While initial trends following the implementation of the Vision Zero campaign indicate promising outcomes for crash reduction,⁹ additional research is necessary to assess the independent effects of individual strategies on protecting vulnerable road users in NYC and examine the implications of potential expansion into other urban environments.

This study aimed to test the effectiveness of three major physical environmental roadway initiatives in preventing injury and death among pedestrians and cyclists in NYC. Interventions were further examined to determine whether surrounding street segment length, a known contributor to vehicular speed,¹⁰ modifies the association between intervention and crash outcomes.

METHODS

Study design

We used a staggered difference-in-difference design to assess the relationship between traffic safety interventions and pedestrian and cyclist crash incidence. The units of analysis were site-months. Intersections or street segments ('sites') that had a selected intervention installed between 1 January 2015 and 1 December 2023 were eligible for inclusion. Sites where installation occurred between 2015 and 2019 were designated as intervention sites while those with installations occurring between 2020 and 2023 were designated as control sites. The study period included 60 months from 1 January 2015 to 31 December 2019 (ie, the period during which intervention sites were installed and control sites were not yet installed). This procedure supported comparability of the intervention and control sites insofar as NYC identified them as eligible and in need of physical environmental interventions.

Variables

We accessed publicly available data for this analysis from NYC Open Data.¹¹ The dependent measure was the presence of any crash that occurred within 100 ft of each site per month. Crash data include all police-reported collisions in NYC in which an individual was injured or killed or in which US\$1000 or more worth of damage occurred. Crashes were grouped according to the person injured (cyclist, pedestrian) and severity (injury, fatality).

The independent measure was physical environmental roadway interventions. Three physical intervention categories which each had publicly available data for installations that occurred between 1 January 2015 and 1 December 2023 were chosen: enhanced crossings, speed humps and turn traffic calming (figure 1). Enhanced crossings are marked high-visibility crosswalks in low-vehicle traffic areas near schools, transit centres and parks where there is no traffic signal or stop sign,¹² speed humps are raised areas of roadway that are designed to reduce vehicle speed¹³ and turn traffic calming are a group of treatments designed to encourage safer turns, such as hardened centrelines and slow turn wedges, installed in areas with high frequency of crash injury.¹⁴

Statistical analyses

For each month and site, we created a binary variable indicating whether crashes had occurred involving cyclist or pedestrian injury or mortality at that time and place. We conducted separate analyses for each intervention type wherein the units of analysis were site-months. There were 169 intervention sites and 16 control sites for enhanced crossings, 1226 intervention sites and 611 control sites for speed humps, and 457 intervention sites and 521 control sites for turn traffic calming. The resultant panel data set for enhanced crossings contained 11 100 site-months (185 sites×60 months); the speed humps data set contained 110 220 site-months (1837 sites×60 months) and the turn traffic calming data set contained 58 680 site-months (978 sites×60 months).

Two-way fixed effects logistic regression models were specified for each exposure (enhanced crossings, speed humps and turn traffic calming) and outcome (cyclist injury or death, pedestrian injury or death) pair. We specified additional models to examine the relationship between turn traffic calming and pedestrian injury and pedestrian fatality separately. All models included fixed effects for both site ID and month to account for unit-specific and time-specific confounding and guard against the small possibility that these interventions affect pedestrian and cyclist volume, and we calculated cluster-robust SEs to account for heteroskedasticity across sites.¹⁵

We assessed the effect modification on the relationship between turn traffic calming and pedestrian outcomes by surrounding street segment length. First, we spatially joined both intervention and control intersections with surrounding street segments and calculated street segment lengths. We identified the length of the longest segment attached to each intersection (a proxy for speeding risk), calculated quartiles for the longest street segment, and assigned these to each intersection. We then conducted stratified analyses to investigate the association between turn traffic calming and crashes involving pedestrian injury or death for each quartile.

We conducted two sensitivity analyses. First, we specified Bayesian conditional autoregressive logistic models, using R-INLA, which calculates the integrated network Laplace approximation of a fully Bayesian model.¹⁶ Models included the independent measure for each intervention, an 'ever-treated' variable, covariates for number of adjacent streets and total length of adjacent streets, a fixed effect for month, a random effect for site ID and a conditional autoregressive random effect that controlled for loss of unit independence, identified using a matrix of adjacent intervention and control sites with queen

contiguity. Second, we used the *did* package developed by Callaway and Sant'Anna¹⁷ to estimate the group-time average treatment effect of each intervention of interest, adjusting for the same roadway characteristics as in the R-INLA models. Analyses were performed by using R V.4.3.1 and ArcGIS Pro V.3.0.0.

Patient and public involvement

The public was not involved in the conduct of this study. All data used in this study are publicly available and deidentified.

RESULTS

Table 1 reports descriptive statistics for included site-months. Of the selected outcomes, crashes involving pedestrian injury occurred most frequently across site-months, followed by crashes involving cyclist injury, pedestrian fatality and cyclist fatality. Characteristics of intervention and control sites can be found in online supplemental table 1. Differences in site characteristics were controlled for implicitly in the two-way fixed effects models by estimating within-unit effects and explicitly in sensitivity analyses.

Negative associations were observed for all intervention-outcome pairs, though only the CI for the relationship between turn traffic calming interventions and pedestrian injury or death did not include the null value of 1 (OR 0.82, 95% CI 0.72 to 0.92). Sensitivity analyses yielded substantively similar results (online supplemental table 2). Furthermore, results showed that installation of turn traffic calming measures decreased the odds of crashes involving pedestrian injury by 16% (OR 0.84, 95% CI 0.74 to 0.95) and crashes involving pedestrian death by 80% (OR 0.20, 95% CI 0.08 to 0.47) (table 2).

In stratified analyses, we observed a dose–responsive relationship between longest street segment length quartile and the association between turn traffic calming and pedestrian injury or death. We found the strongest association and the only one whose CI did not include the null value of 1, for the longest quartile stratum (OR 0.70, 95% CI 0.55 to 0.88), with decreases in the strength of the association for the third quartile (OR 0.80, 95% CI 0.62 to 1.03), second quartile (OR 0.86, 95% CI 0.64 to 1.15) and shortest quartile (OR 0.94, 95% CI 0.75 to 1.18) (table 3).

DISCUSSION

Physical environmental roadway interventions are demonstrably effective strategies for reducing pedestrian and cyclist injury and mortality.^{5 6} This study built on previous research showing the effectiveness of physical environmental roadway interventions in NYC in the pre-Vision Zero era⁸ as well as work on the use of turn traffic calming in other metropolitan areas.^{18 19} Results identify that associations are strongest for turn traffic calming, especially at intersections that abut long street segments. Crashes that occur at higher speeds, which are more likely on longer roads,¹⁰ are high priorities for reduction because they are more likely to be fatal for pedestrians.²⁰ Our results indicate that by prioritising these areas for turn traffic calming interventions, crashes involving pedestrian injury or death could be reduced substantially.

This study has important limitations. Due to the restrictions of the crash data in this analysis, minor incidents and near-misses may not be represented. Additionally, low numbers of pedestrian and cyclist deaths around intervention sites during the study period prevented more detailed analytic breakdowns. Because this study only examined interventions and crashes in NYC, results may not be generalisable to other areas.

The limited resources available to cities for improving traffic safety must be utilised effectively. Our findings suggest that these funds may be best leveraged in reducing pedestrian injury and death if used for turn traffic calming treatments, especially in areas that are more vulnerable to speeding, such as intersections with long road segment lead-ins.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Data availability statement

All data used for this study are publicly available from NYC Open Data (<https://opendata.cityofnewyork.us/>).

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WHAT IS ALREADY KNOWN ON THIS TOPIC

- Vulnerable road users, such as pedestrians and cyclists, are at high risk of injury and mortality due to motor vehicle collisions.
- New York City has implemented new traffic safety measures in the form of physical environmental roadway interventions to combat serious injury and death which have not been systematically evaluated for public health benefit.

WHAT THIS STUDY ADDS

- Turn traffic calming treatments appear to lower the odds of crashes involving pedestrian injury or fatality in New York City.
- Turn traffic calming treatments may be most effective in areas that are particularly prone to speeding, such as intersections that are connected to long street segments.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- The effectiveness of different physical environmental roadway interventions should be considered when choosing how to use limited resources for optimal public health benefit.



Figure 1.
Example images of physical environmental roadway interventions in New York City from left to right: enhanced crossing, speed hump, turn traffic calming treatment.

Table 1.

Descriptive statistics for included site-months, New York City 2015-2019

Outcomes	Enhanced Crossings (N=11100)		Speed Humps (N=110220)		Turn Traffic Calming (N=58680)	
	n	%	n	%	n	%
Pedestrian injured	128	1.15	3642	3.30	5522	9.41
Pedestrian killed	1	0.01	43	0.04	112	0.19
Cyclist injured	39	0.35	1717	1.56	2239	3.82
Cyclist killed	1	0.01	7	0.01	10	0.02

Table 2.

Two-way fixed effects logistic regression analysis of associations between physical environmental roadway interventions and crash outcomes, New York City 2015-2019

Intervention	Outcome	OR	95% CI
Enhanced Crossings	Cyclist injured or killed	0.51	0.14, 1.80
	Pedestrian injured or killed	0.94	0.49, 1.80
Speed Humps	Cyclist injured or killed	0.94	0.79, 1.13
	Pedestrian injured or killed	0.91	0.80, 1.02
Turn Traffic Calming	Cyclist injured or killed	0.89	0.74, 1.07
	Pedestrian injured or killed	0.82	0.72, 0.92
	Pedestrian injured	0.84	0.74, 0.95
	Pedestrian killed	0.20	0.08, 0.47

* Bolded values are statistically significant at an alpha of 0.05

Table 3.

Association between turn traffic calming intervention and crashes involving pedestrian injury or death within longest street segment quartile strata, New York City 2015-2019

Longest Street Segment Quartiles	OR	95% CI
Shortest Quartile	0.94	0.75, 1.18
Second	0.86	0.64, 1.15
Third	0.80	0.62, 1.03
Longest Quartile	0.70	0.55, 0.88

* Bolded values are statistically significant at an alpha of 0.05