The Impact of a Signalized Crosswalk on Traffic Speed and Street-Crossing Behaviors of Residents in an Underserved Neighborhood

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ABSTRACT *Infrastructure improvements such as pedestrian crosswalks that calm traffic and increase access to physical activity opportunities could alleviate important barriers to active living in underserved communities with outdated built environments. The purpose of this study was to explore how the built environment influences street-crossing behaviors and traffic speeds in a low-income neighborhood with barriers to active living in Columbia, Missouri. In 2013, a signalized pedestrian crosswalk and 400-ft-long median was constructed along a busy 5-lane, high-speed arterial highway linking low-income housing with a park and downtown areas. Data collection occurred prior to June 2012, and after June 2013, completion of the project at the intervention site and control site. Direct observation of street-crossing behaviors was performed at designated intersections/crosswalks or non-designated crossing points. Traffic volume and speed were captured using embedded magnetic traffic detectors. At the intervention site, designated crossings increased at the new crosswalk ($p<0.001$), but not at non-designated crossings ($p=0.52$) or designated crossings at intersections ($p=0.41$). At the control site, there was no change in designated crossings ($p=0.94$) or non-designated crossings ($p=0.79$). Motor vehicles traveling above the speed limit of 35 mph decreased from 62,056 (46 %) to 46,256 (35 %) ($p<0.001$) at the intervention site and increased from 57,891 (49 %) to 65,725 (59 %) ($p<0.001$) at the control site. The installation of a signalized crosswalk facilitated an increase in safe street crossings and calmed traffic volume and speed in an underserved neighborhood. We believe these findings have significant public health implications that could be critical to advocacy efforts to improve infrastructure projects in similar communities.*

KEYWORDS *Walking behavior, Pedestrian safety, Traffic, Active living*

INTRODUCTION

Over the past 40 years, there has been a dramatic increase in the prevalence of obesity in the USA, with roughly 155 million adults and 24 million children overweight or obese.¹ Overweight and obesity are catalysts of many health problems, especially in minority populations.² While physical activity (PA) improves

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overall health by lowering the risk for obesity and its related ailments,³ most Americans fall short of current PA guidelines.⁴ Recent studies show that the built environment plays an important role in promoting PA.^{5–10} However, neighborhoods with low-income, minority residents often have low walkability as a result of busy streets;^{11, 12} absent or poorly maintained sidewalks, crosswalks, and parks;^{13–15} and actual or perceived threats to personal safety.^{16, 17} Thus, individuals from these neighborhoods often have limited access to PA facilities and may have a higher risk of developing obesity. In addition, minority populations are at greatest risk for motor vehicle-related pedestrian death, especially in urban areas¹⁸.

There is a paucity of research exploring the behaviors of low-income community residents in context of their neighborhoods.^{12, 13} Supportive environments and communities are fundamental in shaping individual choices to pursue active living when it is accessible, available, and affordable.¹⁹ Numerous studies indicate that proximity and access to parks are associated with active living in both youth and adults.^{5, 7, 9, 11, 13, 20–23} Kaczynski et al.²² found that participants needing to cross high-speed roads to access the closest park were less likely to use parks. Similarly, Handy et al.⁷ found that key neighborhood design features including low traffic and general walkability directly influence PA. Thus, built environment improvements, such as the installation of crosswalks that calm traffic and increase accessibility to PA opportunities, could alleviate barriers to active living. Although one study has examined pedestrian use of crosswalks²⁴, this is the first study to our knowledge examining the importance of crosswalks to support active living in a low-income neighborhood. The purpose of this study was to explore whether redesigned pedestrian crossing infrastructure influenced street-crossing behaviors and calmed traffic across a high-speed arterial.

METHODS

This project offered the opportunity to take advantage of a natural experiment in the community and study the effect of a modern, pedestrian crossing system linking low-income housing with a park and downtown areas and will help expand the limited body of knowledge on the use of pedestrian crosswalks. Columbia Missouri's Douglass Park Neighborhood—home to the city's largest populations of low-income and racial/ethnic minority residents—is bisected by Providence Road, a five-lane major arterial highway.²⁵ According to City of Columbia data, Providence Road carries 23,000 vehicles per day at maximal speeds of 75 mph, creating a formidable barrier between a dense residential area of low-income housing on the west side and a public park, high school, and access to downtown Columbia on the east side. With no marked or signalized crosswalks, there has been no safe way to cross Providence Road prior to the intervention except for: (1) an unsafe, poorly designed, non-American with Disabilities Act (ADA) accessible and rarely used pedestrian footbridge and (2) two distant, unmarked intersections far from where pedestrians typically cross the street. Pedestrians frequently crossed the road between moving traffic—a dangerous practice that also created frustration for Columbia motorists. In spring 2013, an infrastructure project implemented by the City of Columbia attempted to address these concerns. A signalized pedestrian crosswalk and 400-ft median was completed along a quarter-mile section of Providence Road and the existing pedestrian bridge was demolished and removed.

Study Population. Columbia Missouri's Douglass Park Neighborhood includes 626 adults and 196 children (approximately 477 households) with a median household income of \$8359 per year. In addition, 57 % of families live below the federal poverty level, 48 % of residents over 16 are unemployed, and only 31 % of adults have a high school diploma. The neighborhood racial demographic is Black (59 %), White (36 %), mixed-race (3 %), and Asian (2 %).²⁶ Most of the target population live within one of the 294 public housing family units managed by the Columbia Housing Authority²⁷ directly west of the intervention site (Fig. 1), of which 67 % of families live below poverty, 82 % of residents over 16 are unemployed, and 77 % of children are raised in a single-parent household.²⁶

Study Location. The intervention site along Providence Road next to Douglass Park was the location of a major infrastructure project to install a signalized crosswalk across a busy five-lane, high-speed arterial highway (Figs. 1 and 2). This study focused on street-crossing behaviors along Providence Road directly to the west of Douglass Park. A control site was selected along another five-lane, arterial highway to control for street-crossing behaviors (College Avenue). The site was selected based on relevant characteristics of the neighborhood (e.g., size, income level, racial profile), as well as the corresponding street (e.g., number of lanes, typical traffic volumes/speeds, pedestrian crossing facilities).

Data Collection Protocol and Study Instruments. All protocols were approved by the University of Missouri Institutional Review Board. Data collection occurred at both intervention and control sites before (baseline; 2012) and after (post-intervention; 2013) the signalized crosswalk installation and pedestrian bridge removal. Street-crossing behaviors were collected using direct observation. Measurements took place concurrently at both sites for a total of 21 shifts over the same 2-week period in June 2012 and June 2013. Street-crossing observations were

FIG. 1 Location of the signalized pedestrian crosswalk and 400-ft median within the Douglass Park neighborhood of Columbia Missouri, where the majority of the study's target population live. A graphic depiction of the salient features of the median and crosswalk are shown on the right of the figure.

FIG. 2 The intervention site along the five-lane high-speed arterial highway (Providence Road) in Columbia Missouri. The signalized pedestrian crosswalk and 400-ft median are shown from **a** the north and **b** the south. Key features of the intervention site include **a** American with Disabilities Act (ADA) accessible median and **c** striped and signalized crosswalk allowing easier access to downtown Columbia from the public housing units to the west of the intervention site.

recorded during 3-h-long periods (7:30–8:30 a.m., 12:30–1:30 p.m., 3:30–4:30 p.m.). Pedestrians were counted who crossed the intervention site (Providence Road) at or between its intersections with Ash Street to the South and Worley Street to the North (a distance of one-quarter mile). The same protocol was utilized at the control site (College Avenue), recording crossing activity between its intersections with Rollins Road to the South and University Avenue to the North (also a distance of one-quarter mile). Measures included gender (male, female), race/ethnicity (White, Black, Hispanic, Asian, other/unsure), and age group (1–12, 13–20, 21–59, 60+). Trained observers were located at three street locations along both the intervention and control sites.

The study also monitored traffic speed and volume at the intervention and control sites, before and after installation of the signalized crosswalk. Traffic data were collected with Nu-metrics Hi-Star (Uniontown, PA) magnetic traffic detectors embedded into four travel lanes at the intervention and control sites. Detectors calculated vehicle speed and stored speed and volume data in 1-h time bins for 150 h in both 2012 and 2013.

Data Analysis. Descriptive statistics were used to describe street crossings within each demographic and crossing behavior category. Street crossings that occurred without assistance from pedestrian infrastructure (i.e., pedestrian foot bridge, new signalized crosswalk, intersection crosswalks) were grouped as non-designated crossings. Any crossings that utilized pedestrian infrastructures were grouped as

designated crossings. The designated crossing grouping at the intervention site was further refined as either designated crossing at the intersection or designated crossing at the bridge/new crosswalk to capture changes in pedestrian behavior related to the intervention.

Data was analyzed using SPSS (Cary, NC). Analysis of covariance (ANCOVA) models, controlling for temperature, were used to examine changes in pedestrian crossings to determine if the intervention had a significant impact upon crossing behaviors at the intervention site. Prior to running the ANCOVA models, the count distributions were examined for goodness of fit and normal distribution and log transformations were used for subsequent ANCOVA models.

Our analysis involved a three-step process: (1) assessment of site differences, (2) zone differences by site, and (3) differences by demographics. To assess site differences in pedestrian crossings, a three-way ANCOVA model was run for the dependent variable (overall count) with the independent variables of year (2012, 2013), site location (intervention street, control street), and designation zone (non-designated crossing, designated crossing; the two designated zones at the intervention site were grouped for comparison purposes), and the site location $\times$ year $\times$ designation zone interaction. When a significant interaction was observed, a two-way ANCOVA was run for each site separately for the dependent variable (overall count) with the independent variables of year (2012, 2013), designation zone (control site: non-designated crossing, designated crossing; intervention site: non-designated crossing, designated crossing at the intersections, designated crossing at the bridge/crosswalk), and the year $\times$ designation zone interaction, controlling for temperature. Pairwise Sidak post hoc tests examined where zone differences occurred.

At the intervention site, three ANCOVA models, controlling for temperature, were run to examine differences in crossing behaviors by year for each dependent variable including: age, gender, and race/ethnicity. Due to small sample sizes the race/ethnicity categories of Hispanic, Asian, and other/unsure were combined into one other race/ethnicity category. The first ANCOVA model examined overall count by year (2012, 2013), designation zone (non-designated crossing, designated crossing at intersection, and designated crossing at bridge/new crosswalk), age and year $\times$ designation zone $\times$ age interaction. The second ANCOVA model used gender instead of age and examined the year $\times$ designation zone $\times$ gender interaction. The third ANCOVA model used race/ethnicity in place of age and examined the year $\times$ designation zone $\times$ race/ethnicity interaction. Pairwise Sidak post hoc tests examined where zone differences occurred for each user demographic group.

Descriptive statistics were used to describe recorded traffic volumes and speeds. The data bins of recorded traffic speed and volume were averaged for both the intervention and control sites in 2012 and 2013. Traffic speed was dichotomized as either speeding (≥ 35 mph) or not speeding (< 35 mph). Chi-square was used to analyze traffic data obtained from the sensors.

RESULTS

Changes in Crossing Behaviors

Descriptives. The total recorded pedestrian crossings at the intervention site was 1408 in 2012 and 1352 in 2013 (Table 1). Males were more prevalent in both 2012 and 2013; 932 (67 %) and 888 (66 %), respectively. In both years, adults comprised

TABLE 1 Descriptive statistics of pedestrian crossing behaviors

		Intervention street				Control street			
		Baseline (2012)		Follow-up (2013)		Baseline (2012)		Follow-up (2013)	
		<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)	<i>n</i>	(%)
Total		1408	100	1352	100	4330	100	3848	100
Age	Child	171	12.3	132	9.8	13	0.30	17	0.44
	Teen	380	27.3	327	24.2	1246	28.8	270	7.0
	Adult	806	57.8	852	63.0	2991	69.2	3478	90.4
	Senior	37	2.7	29	2.1	74	1.7	71	1.9
Gender	Male	932	66.5	888	65.7	2452	56.7	2219	57.7
	Female	470	33.5	459	33.9	1875	43.3	1624	42.2
Race/ethnicity	White	404	28.7	395	29.2	3374	78.0	2964	77.0
	Black	966	68.6	869	64.3	222	5.1	233	6.1
	Asian, Hispanic, other	38	2.7	87	6.4	730	16.9	650	16.9
Designation zone	Non-designated crossing	868	61.7	699	51.7	2020	46.7	1745	45.4
	Designated crossing at the intersection	488	34.7	471	34.8	2310	53.4	2103	54.7
	Designated crossing at the bridge/new crosswalk	52	3.7	182	13.5	—	—	—	—

the majority of crossings ($n=806$ [58 %], 2012; $n=852$ [63 %], 2013) followed by teens ($n=380$ [27 %], 2012; $n=327$ [24 %], 2013), and children ($n=171$ [12 %], 2012; $n=132$ [10 %], 2013) while seniors comprised less than 3 % of the total population in both years ($n=37$, 2012; $n=29$, 2013). Approximately 65 % of the population was Black ($n=966$, 2012; $n=869$, 2013) and 29 % of the population was White ($n=404$, 2012; $n=395$, 2013) while Asian, Hispanic, and other comprised 3 % ($n=38$) and 6 % ($n=87$) in 2012 and 2013, respectively.

At the control site, the total recorded pedestrian crossings were 4330 in 2012 and 3848 in 2013 (Table 1). Males were more prevalent, 2452 (57 %) and 2219 (58 %) in 2012 and 2013, respectively. In both years, adults comprised the majority of crossings ($n=2991$ [69 %], 2012; $n=3478$ [90 %], 2013) followed by teens ($n=1246$ [29 %], 2012; $n=270$ [7 %], 2013) and seniors ($n=74$ [2 %], 2012; $n=71$ [2 %], 2013), while children comprised less than 0.5 % of the total population in both years ($n=13$, 2012; $n=17$, 2013). More than 77 % of the population was White ($n=3374$, 2012; $n=2964$, 2013). Approximately 17 % of the population was Asian, Hispanic, or other ($n=730$, 2012; $n=650$, 2013) while 6 % of the population was Black ($n=222$, 2012; $n=233$, 2013).

Changes in Pedestrian Crossing Behaviors. The three-way ANCOVA showed a significant interaction among year, site location, and designation zone ($F=8.270$; $p<0.001$). The two-way ANCOVA for each site indicated a significant interaction between year and designation zone in crossing behaviors at the intervention site (non-designated crossing, designated crossing at the intersections, designated crossing at the bridge/crosswalk; $F=12.824$, $p<0.001$). Pairwise comparisons at the intervention site revealed a significant increase in designated crossings at the bridge/new crosswalk from 2012 to 2013 (0.64 ± 0.05 to 1.05 ± 0.05 ; $p<0.001$), but no change in non-designated crossings (1.53 ± 0.05 to 1.49

± 0.05 ; $p=0.52$) or designated crossings at intersections (1.35 ± 0.05 to 1.41 ± 0.05 ; $p=0.41$) (Fig. 3). There was no significant interaction between year and designation zone at the control street ($F=0.022$, $p=0.88$).

Changes in Pedestrian Crossing Behaviors by Demographics. Because pairwise comparisons at the intervention site revealed that use of the new crosswalk was significantly higher in 2013 compared to the pedestrian bridge in 2012 ($p<0.001$), we further examined crosswalk usage by demographic (age, gender, race/ethnicity) (Table 2).

Child counts did not show an increased use of the new crosswalk in 2013 compared to 2012 but showed a strong trend (0.75 ± 0.05 vs 0.59 ± 0.07 ; $p=0.065$). In addition, child counts showed a significant decrease in non-designated crossings from 2012 to 2013 (0.85 ± 0.05 vs 0.65 ± 0.05 ; $p=0.003$). There was significant increased use of the crosswalk for teens (0.52 ± 0.07 vs 0.72 ± 0.05 ; $p=0.02$) and adults (0.52 ± 0.06 vs 0.76 ± 0.05 ; $p=0.001$), while senior use did not change (0.51 ± 0.20 vs 0.52 ± 0.11 ; $p=0.97$). Males (0.57 ± 0.05 vs 0.80 ± 0.05 ; $p=0.002$) and females (0.54 ± 0.07 vs 0.86 ± 0.05 ; $p<0.001$) both demonstrated increased use of the new crosswalk. In addition, females showed a strong trend toward decreased non-designated crossings (1.13 ± 0.05 vs 1.01 ± 0.04 ; $p=0.059$). Use of the crosswalk significantly increased for Black (0.62 ± 0.05 vs 0.93 ± 0.05 ; $p<0.001$), but did not change for either White (0.45 ± 0.09 vs 0.63 ± 0.05 ; $p=0.08$) Asian, Hispanic, or other (0.55 ± 0.14 vs 0.60 ± 0.10 ; $p=0.08$). Asian, Hispanic, and other demonstrated increased non-designated crossings (0.51 ± 0.06 vs 0.71 ± 0.07 ; $p=0.03$) and designated crossing at intersections (0.54 ± 0.06 vs 0.72 ± 0.05 ; $p=0.02$).

Changes in Traffic Volume and Speed. Total traffic volume at the intervention site fell from 134,850 vehicles in 2012 to 133,881 in 2013 ($p<0.001$). Motor vehicles traveling above the 35 mph speed limit decreased from 62,056 (46 %) in 2012 to 46,256 (35 %) in 2013 ($p<0.001$) (Fig. 4). Total traffic volume at the control site fell from 119,515 in 2012 to 111,805 in 2013 ($p<0.001$). However, motor vehicles traveling above the 35 mph speed limit increased from 57,891 (48 %) in 2012 to 65,725 (59 %) in 2013 ($p<0.001$) (Fig. 4).

FIG. 3 Pairwise comparisons showing changes in non-designated crossings, designated crossings at intersections, and designated crossings at bridge/new crosswalk at the intervention site from 2012 to 2013. *Denotes significant increase from 2012 to 2013.

FIG. 4 Chi-square analysis showing changes in number of vehicles traveling over speed limit (35 mph) at the intervention site compared and control site from 2012 to 2013. *Denotes significant change from 2012 to 2013.

DISCUSSION

Residents of low-income neighborhoods have the highest levels of sedentary behavior and obesity²⁸, yet few studies have evaluated whether crosswalk infrastructure facilitates access to PA opportunities and promotes active living. The present study found that the construction of a modern, traffic-calming, pedestrian crossing system linking low-income housing with a park and downtown areas resulted in an increase in safe street-crossing behaviors and a decrease in traffic speed.

Crossing Behaviors and Traffic Speed. Designated crossings at the new crosswalk increased compared to the pedestrian bridge from baseline to post-intervention. The significant year by zone interaction at the intervention site, but not at the control site indicates that the intervention made a difference, i.e., people chose to use the new crosswalk more than the old footbridge. These findings are consistent with other studies that have suggested improved traffic safety encourages active transportation.^{29, 30} A key finding in this study was that children and teens either showed a strong trend or an increase use of the new crosswalk. Installation of a crosswalk in a previous study was shown to encourage safer crossings by youth proportionally greater to other age groups.²⁴ There was also a significant decrease in non-designated crossings for children, indicating a reduction in dangerous street-crossing behavior (such as dodging traffic). Parents of children in high-risk lower income neighborhoods often need to teach children how to deal with exposure to high traffic areas;³¹ thus, the tendency toward increased safe crossings observed in children and teens as well as the decrease in unsafe crossings in children suggest that both social and environmental factors may impact youth pedestrian behavior.^{6, 29, 31–33} We also found a significant increase in crosswalk usage by adults, but not by seniors. These findings contrast Morrison et al.³⁰ who reported increased use in senior populations after the installation of a zebra crosswalk. However, a more recent study by King³⁴ suggested that for seniors, the attributes of the social environment that promote safety and social coherence may be of greater importance than the characteristics of the built environment that promote active behaviors.

Our findings also suggest that the installation of a crosswalk can promote increased safe crossing behaviors among low-income African-Americans. This finding adds to those of Sisiopiku and Akin³⁵ who reported that signalized crosswalks help channel pedestrian traffic across age and gender. While studies have suggested that among low-income, non-white communities, environmental

factors are less directly related to levels of walking^{36, 37}; this study reveals that built environmental factors can encourage the adoption of safe crossing behaviors.

At the intervention street, there was a significant decrease in the overall traffic volume and speeding traffic, suggesting that a signalized crosswalk helped to calm traffic and improve conditions necessary for safer access for PA opportunities. These findings are also consistent with studies reporting that sidewalks, crosswalks, and traffic-calming measures increase pedestrian safety.^{38, 39} Within the Douglass Park neighborhood in Columbia MO, these findings have particular relevance as two children were struck by cars and killed while trying to cross the intervention street back in the 1970s when there was no crosswalk or pedestrian bridge. Thus, the importance of observing both a change in street-crossing behavior as well as a calming effect on existing traffic has significant public health implications that could be critical to advocacy efforts to improve infrastructure projects in similar communities.

Study Limitations and Future Research. This study has several limitations to consider: First, construction was completed less than 4 months before the 2013 data collection. This brief interval may not have been sufficient to capture full community behavior changes surrounding the new infrastructure; additionally, it is impossible to separate out any novelty affect that may be present in the data. A planned follow-up evaluation will help to establish accurate community adoption behaviors and behavioral trends related to the signalized crosswalk across multiple years. Further, the present study only examined the crossing behaviors and traffic speed during June. Future studies might consider broadening the scope of inquiry to capture use patterns throughout the changing seasons.

It is also possible that unanticipated environmental or policy changes unrelated to the intervention may have affected crossing behaviors. These changes include occupancy turnover rates in the Columbia Housing Authority housing units and changes in crime levels that may affect actual and perceived safety—especially influential to community use of Douglass Park. However, these are commonly faced challenges in natural experiments. Further, while the present study utilized predominantly higher levels of the social ecological model (SEM) (i.e., community and public policy) to characterize the relationship between people and their social and physical environments⁴⁰, the study may have benefited from examining relationships across multiple levels of the SEM to better understand the factors that impact human behavior.

CONCLUSIONS

The installation of the signalized crosswalk facilitated an increase in safe street crossings and calmed traffic volume and speed in an underserved neighborhood compared to a control site without infrastructure changes. Notably, there were increases in safe street-crossing behavior for children and teens and a decrease in unsafe street-crossing behaviors for children. Taken together, these findings suggest that built environment improvements encouraged safe access to a neighborhood park and downtown areas for neighborhood residents and youth. Since there are only a few studies regarding pedestrian infrastructure interventions and access to physical activity opportunities, this study could have considerable influence on future policy initiatives that strive to create pedestrian-friendly built environments and increase overall community physical activity levels.

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