Neighborhood Road Environments and Physical Activity Among Youth: The CLAN Study

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ABSTRACT *We examined associations between objective measures of the local road environment and physical activity (including active transport) among youth. There is little empirical evidence of the impact of the road environment on physical activity among children/adolescents in their neighborhoods. Most recent studies have examined perceptions rather than objective measures of the road environment. This was a cross-sectional study of children aged 8–9 years (n=188) and adolescents aged 13–15 years (n=346) who were participants in the 3-year follow-up of the Children Living in Active Neighborhoods (CLAN) longitudinal study in Melbourne, Australia. At baseline (2001), they were recruited from 19 state primary schools in areas of varying socioeconomic status across Melbourne. Habitual walking/cycling to local destinations was parent-reported for children and self-reported for adolescents, while moderate-to-vigorous physical activity (MVPA) outside school hours was recorded using accelerometers. Road environment features in each participant's neighborhood (area of radius 800 m around the home) were measured objectively using a geographical information system. Regression analyses found no associations between road environment variables and children's likelihood of making at least seven walking/cycling trips per week to neighborhood destinations. Adolescent girls residing in neighborhoods with two to three traffic/pedestrian lights were more likely to make seven or more walking/cycling trips per week as those whose neighborhoods had fewer traffic lights (OR: 2.7; 95% CI: 1.2–6.2). For adolescent boys, residing on a cul-de-sac, compared with a through road, was associated with increases in MVPA of 9 min after school, 5 min in the evenings, and 22 min on weekend days. Speed humps were positively associated with adolescent boys' MVPA during evenings. The road environment influences physical activity among youth in different ways, according to age group, sex and type of physical activity.*

KEYWORDS *Child, Adolescent, Physical activity, Neighborhood, Safety.*

INTRODUCTION

There is growing concern that children's free play and participation in physical activity is becoming increasingly constrained,^{1–4} with children spending less time playing outdoors,¹ using the neighborhood less for errands or for meeting friends² and less likely to walk or cycle to school and other destinations than previous generations.^{3,4} Activities such as active forms of transport⁵ and outdoor play^{6,7} have been shown to make an important contribution to children's overall physical activity, and the health benefits of regular physical activity during childhood and adolescence are well-documented.^{8,9} In addition, activities such as active transport and outdoor play promote independence, exploration of nature and the built

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environment, development of social skills, and imaginative play without continual surveillance by adults.^{2,3} Thus, understanding potential reasons for declines in children's use of the neighborhood as a venue for physical activity is important.

One reason for declining levels of physical activity in the neighborhood is parents' fear for their children's safety, related primarily to road safety and concern about strangers,^{3,10-13} with parental concern about neighborhood safety being negatively associated with children's physical activity levels.¹⁴ An English study³ has shown that more parents of 7- to 11-year olds curtail their children's active transport (e.g., walking, cycling) due to concerns about road safety than "stranger danger". These fears may be substantiated by statistics showing that transport accidents are the leading cause of death by injury among children in developed nations,¹⁵ with most children injured in road accidents being pedestrians.³ Furthermore, child pedestrian injuries are most likely to occur on local streets¹⁶ and within 500 m of home.¹⁷

Despite these statistics, there is currently little empirical evidence of the impact of road safety on physical activity among children and adolescents. Parental perceptions of unsafe road environments have been negatively associated with walking/cycling among 10- to 12-year olds¹⁸ and adolescents¹⁹ in Australian studies, and adolescent girls' own perception that local roads were safe has been positively associated with both walking for exercise and walking for transport.¹⁹ However, other studies have found no association between adolescents' perceptions of road safety and overall physical activity.²⁰

Even fewer studies have considered how aspects of the road environment designed to improve road safety or reduce traffic flow/speed are related to physical activity among youth. Such research is pertinent, as the emphasis of road safety initiatives has shifted from education to passive interventions such as traffic calming.¹⁷ Initiatives such as speed restrictions in built-up areas (e.g., 50 km/h in Victoria, Australia)²¹ and speed humps are associated with reduced risk of child pedestrian injury,²² but little is known about their impact on physical activity among youth. The aim of this study is to examine associations between objective measures of the road environment, and the physical activity and active transport of children and adolescents, outside school hours, when there may be opportunities to be active in the neighborhood. This study tests the hypothesis that the presence of road environment measures which may be relevant to safety is associated with greater habitual walking/cycling and moderate-to-vigorous physical activity (MVPA) outside school hours.

METHODS

Sample

Data were drawn from a 5-year longitudinal study entitled Children Living in Active Neighborhoods (CLAN).^{18,23,24} This paper refers only to data from the 3-year follow-up, when the road environment was first examined using geographical information system (GIS). At baseline (2001), children were recruited from 19 state primary schools in areas of varying socioeconomic status (SES) across Melbourne, Australia. At participating schools, the study was described to all children aged 5-6 years ($n=1,093$) and 10-12 years ($n=2,096$), and information about the study was sent home to parents. Children were eligible to participate only if active consent (indicated by parents signing a consent form on behalf of their children) was

received. At baseline, the study sample comprised two cohorts: cohort 1 had 295 children aged 5–6 years and a parent for each (27% response rate), and cohort 2 consisted of 919 10- to 12-year olds and a parent for each (44% response rate).^{23,24} Further details of sample selection are published elsewhere.^{18,23,24}

Ethics approval for this study was obtained from the Deakin University Ethics Committee, the Department of Education and Training Victoria, and the Catholic Education office. Among participants who agreed at baseline to be recontacted in the future, active informed consent for participation in the follow-up was obtained from 76% ($n=191$) of children aged 5–6 years at baseline (cohort 1) and 64% ($n=416$) of children aged 10–12 years at baseline (cohort 2). Data collection took place between July and December, 2004. Questionnaire data were collected from parents (both cohorts) and adolescents in cohort 2. Each participant wore an accelerometer. For the rest of the paper, participants in cohort 1 will be referred to as “children” and those in cohort 2 as “adolescents”.

Measures

Active Transport Parents of children reported how frequently their child usually walked/cycled to 15 specific destinations, while adolescents self-reported this information. Frequency values (in parenthesis) were assigned to each response category: (0) “Not within walking/riding distance”; (0) “Never/rarely”; (0.5) “Less than once per week”; (1.5) “1–2 times per week”; (3.5) “3–4 times per week”; (5.5) “5–6 times per week”; and (7) “Daily”. Neighborhood destinations included bike/walking tracks, friends’ houses, sports venues/leisure centers, skate ramps, parks/playgrounds, waterways, beach, other open spaces, public transport, school, amusement arcades, DVD rental stores, convenience stores, takeaway/fast food outlets, and other shops or destinations. These measures were adapted from an existing instrument that included eight destinations.¹⁸ Frequencies of walking/cycling trips to all destinations were summed and dichotomized on conceptual grounds as less than seven trips per week and greater than or equal to seven trips per week to identify habitual walking/cycling that equates to an average of at least one trip per day. One-week test–retest reliability for total number of trips per week was acceptable (intraclass correlation, ICC>0.5) for children ($n=53$) and adolescents ($n=80$), while agreement was high for the dichotomized variable (76% and 96%, respectively).

Objectively Assessed Physical Activity Participants were asked to wear an accelerometer [Manufacturing Technologies, Inc. (MTI) (formerly Computer Science and Applications, Inc.) Model 7164 (Actigraph, Inc., Florida, USA)] attached to an elasticized belt at hip-level for eight consecutive days, removing only for sleeping, showering, or swimming.²³ Accelerometer data files were downloaded and entered into a data reduction program. Daily accelerometer counts were examined, and data were excluded for any day on which the total number of counts recorded was less than 10,000 counts (suggesting the accelerometer had not been worn as requested) or greater than 20 million counts (suggesting the accelerometer had malfunctioned).^{23,24} Mean duration (minutes/day) spent in physical activity of moderate-to-vigorous intensity (i.e., greater than or equal to three METs) was calculated for three specific periods on weekdays and for whole weekend days using an established regression equation²⁵ that identifies an appropriate counts/minute threshold for a given physical activity intensity dependent on the age of the child. The weekday periods included: before school (6 A.M. to first school bell); after school (last school

bell to 6 P.M.); evening (6–9 P.M.). These three durations were also summed to compute total average duration of MVPA outside school hours.

Objective Measures of Road Environment A GIS, Arcview GIS 3.3 (Environmental Systems Research Institute, Inc., California, 2002), was used to examine objective measures of the road environment within an 800 m radius of each participant's home. Parents of 10- to 12-year-old children had previously reported 1,600 m as a maximum walking distance for their children.¹⁸ This is consistent with a study that found that most child pedestrian injuries took place within 500 m of the home.¹⁷ Spatial data were provided by the State Government of Victoria (address points, cadastral data, road network data) and overlaid with street directory maps (Ausway, Mount Waverley, Australia, 2003). The residential address of each participant was geocoded (i.e., converted to representative coordinates). Eight indicators of the road environment within 800 m of each child's home were generated. Before analysis, each indicator was categorized into "low", "medium", and "high" groupings based on a tertile split. The indicators were:

Street Network

Total length of local roads—total length (km) of roads classed as "local", "two-wheel drive", or "four-wheel drive" within the State Government of Victoria's road hierarchy²⁶ was computed. These roads generally have a maximum speed limit of 50 km/h;²¹

Local road index ratio of total length of local roads to total length of all roads, i.e., the ratio of roads with lower speed limits/traffic volume to all roads;

Intersection density—usually refers to the number of intersections per unit of area,^{27,28} but neighborhoods in this study had identical area, so number of intersections per neighborhood was entered into analyses. Intersection density is positively associated with increased street connectivity and greater traffic calming;²⁷

Residing on a cul-de-sac—indicates whether or not a participant resided on a cul-de-sac or no-through road (defined in GIS as a road segment that contained a road end). This measure was verified by examining the street directory. Cul-de-sacs are prevalent in neighborhoods with low street connectivity,²⁹ but may be regarded by parents as safe play venues, due to lack of through traffic and opportunities for parental surveillance from home;³⁰

Pedestrian Network

Total length of walking tracks—total length (m) of walking tracks identified from road network data;²⁶

Reengineering of road environment

Indicators generated by counting corresponding street directory symbols were: *total numbers of speed humps*, which were associated with reduced risk of child pedestrian injury in a US study;²² *gates/barriers on roads* (these may have a traffic calming effect); "slow points" or sections of road narrowing (i.e., chicanes and sections of intentionally narrowed road) which may encourage slower driving³¹ and *total number of traffic and/or pedestrian lights*.

DATA ANALYSIS

For each cohort, logistic regression analyses were performed using Stata SE/8 (Stata Corporation, Texas, USA, 2003) to examine associations between road environment measures and the likelihood of making seven or more walking/cycling trips in the

neighborhood per week. In addition, linear regression analyses were performed to examine associations between each road environment measure and time spent in MVPA during each specific weekday periods and on weekends for each cohort. Road environment measures and mean minutes of MVPA were entered into these linear regressions as continuous variables. Initially, bivariate logistic and linear regression analyses were performed. Multiple logistic and linear regression analyses were then performed including predictor variables which were significantly associated ($p < 0.05$) with the outcomes in bivariate analyses. All predictor variables were assessed for multi-collinearity using correlation coefficients between each pair of variables and the variance inflation factor (VIF).³² If significant variables were highly correlated (i.e., $VIF > 2.0$), only the variable with the highest unadjusted Beta was used. The effect of clustering by school of recruitment was examined (by including the “cluster” option with regression analyses using Stata) but had little impact on the results and therefore is not shown here. While clustering by school recruitment at baseline may have had an effect at baseline, this was not the case 3 years later when children were attending a large variety of schools. In particular, most adolescents had made the transition from junior to senior school. Please note that in Victoria, Australia, attendance at government-run schools is not determined by residence within a school’s catchment area, and parents may choose from a range of government-run schools and private schools. Furthermore, maternal education was examined as an indicator of individual-level SES but was found to be associated significantly with the outcome measures of MVPA during specified periods, and hence was excluded from further analyses.

RESULTS

Data were analyzed for 188 children (44% boys) with mean age 9.1 (SD 0.4) years and 346 adolescents (53% boys) with mean age 14.5 (SD 0.6) years. For all these participants, accelerometer data and GIS data were available (i.e., accelerometer had been worn as requested and had not malfunctioned, and child had not moved to a residence outside the scope of the study by follow-up.) The parent survey was completed mainly by mothers (85%) and around 75% of parents were married. Over 40% of mothers were tertiary educated. On average, children made 6.2 (SD 5.2) walking/cycling trips per week, this being less than adolescents who made 11.9 (SD 9.5) trips per week. However, children recorded, on average, more time in MVPA outside school hours on weekdays and more MVPA on weekend days compared with adolescents (Table 1). The variability in values of each road safety measure is shown in Table 2.

Road Environment and Walking/Cycling Trips

For children, there were no significant associations between road environment measures and the likelihood of making seven or more walking/cycling trips per week (data not shown). Among adolescent girls, however, there were strong associations between these variables (Table 3). The multiple logistic regression model revealed that adolescent girls residing in neighborhoods with a medium number (i.e., two or three sets) of traffic/pedestrian lights were more likely to make seven or more walking/cycling trips per week than those whose neighborhoods had fewer traffic lights (OR: 2.7; 95% CI: 1.2–6.2), with the multiple model explaining 11% of the variance. For adolescent boys, the multiple logistic regression model revealed that boys residing in neighborhoods with a medium total length of local roads (i.e., 14.5–

TABLE 1 Mean (SD) time spent in moderate-to-vigorous physical activity (MVPA) by age-group

Time period	Children (cohort 1) mean (SD) minutes MVPA		Adolescents (cohort 2) mean (SD) minutes MVPA	
	Boys	Girls	Boys	Girls
Before school ^{a,b}	23.2 (11.7)*	20.2 (18.1)*	11.2 (6.8)	7.9 (5.3)**
After school ^{a,c}	43.9 (13.6)*	43.2 (14.4)*	26.7 (15.1)	19.9 (10.7)**
Evenings ^{a,d}	28.1 (12.1)*	29.7 (13.3)*	11.5 (9.5)	10.7 (7.8)
Non-school hours (weekdays) ^{a,e}	95.1 (26.2)*	93.1 (30.9)*	49.8 (22.3)	37.7 (16.7)**
Weekend days ^a	168.6 (83.4)*	158.5 (78.0)*	72.12 (44.06)	48.53 (33.39)**

* $p < 0.001$: Independent samples t test—significant differences between cohorts within sex

** $p < 0.001$: Independent samples t test—significant differences between boys and girls within cohort

^aData for 4+ weekdays available

^b6 A.M. to start of school day

^cEnd of school day to 6 P.M.

^d6–9 P.M.

^e6 A.M. to start of school day and end of school day to 9 P.M.

17.8 km) were more likely than those residing in areas with a low total length to make seven or more such trips (OR: 3.0; 95% CI: 1.0–9.1). Those boys whose neighborhoods contained medium (i.e., two to seven) rather than low numbers of speed humps were less likely to make seven or more walking/cycling trips per week (OR: 0.3; 95% CI: 0.1–0.9), with the multiple model explaining 11% of the variance.

Road Environment and Overall Physical Activity

Significant associations between road environment measures and MVPA among children are shown in Table 4. For younger girls, each additional 10 km of local roads was associated with a decrease of 6 min in MVPA before school, while each additional hundred intersections was associated with almost 7 min less MVPA before school. Because these variables were highly correlated, they were not entered into a multiple model. In another multiple regression model, the number of intersections and total length of walking tracks remained significantly negatively associated with younger boys' MVPA on weekends. This model was highly significant ($p < 0.001$) and explained 21% of the variance. In a further multiple regression model for younger

TABLE 2 Median (and range of) values of road environment measures within participants' neighborhoods (by cohort)

Measure of road environment (within 800 m radius of home)	Children median (min, max)	Adolescents median (min, max)
Total length of local roads (km)	16.2 (1.6, 31.8)	16.1 (0, 36.6)
Local road index	0.8 (0.3, 1.00)	0.8 (0.3, 1.00)
Intersection density	89 (4, 255)	87 (1, 279)
Total length of walking tracks (m)	26.8 (0, 3707)	0 (0, 3977)
Total no. of speed humps	4 (0, 82)	5 (0, 99)
Total no. of gates/barriers on road	0 (0, 8)	0 (0, 8)
Total traffic "slow points" or sections of road narrowing	0 (0, 15)	0 (0, 24)
Total no. of traffic and/or pedestrian lights	3 (0, 16)	3 (0, 21)

TABLE 3 Road environment measures and likelihood of adolescents making seven or more walking/cycling trips per week

Predictor	Boys		Girls	
	Unadjusted	Adjusted ^a	Unadjusted	Adjusted ^a
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Local road length				
Lowest tertile	1.0	1.0	1.0	—
Middle tertile	3.46* (1.26–9.50)	3.02* (1.01–9.06)	1.76 (0.84–3.68)	—
Highest tertile	2.64* (1.08–6.47)	1.79 (0.66–4.88)	1.69 (0.77–3.68)	—
Local road index				
Lowest tertile	1.0	—	1.0	—
Middle tertile	0.63 (0.25–1.62)	—	1.42 (0.62–3.28)	—
Highest tertile	0.59 (0.22–1.58)	—	0.53 (0.26–1.11)	—
No. of intersections				
Lowest tertile	1.0	—	1.0	1.0
Middle tertile	1.65 (0.64–4.23)	—	2.41* (1.41–5.07)	1.82 (0.80–4.13)
Highest tertile	1.77 (0.71–4.41)	—	3.81** (1.68–8.66)	2.14 (0.78–5.86)
Total length of walking tracks				
Lowest tertile	1.0	—	1.0	—
Middle tertile	0.63 (0.21–1.93)	—	1.92 (0.77–4.84)	—
Highest tertile	1.24 (0.52–2.95)	—	1.59 (0.79–3.17)	—
Live in cul de sac				
No	1.0	—	1.0	1.0
Yes	1.06 (0.42–2.74)	—	0.36** (0.18–0.70)	0.51 (0.24–1.10)
No. of speed humps				
Lowest tertile	1.0	1.0	1.0	1.0
Middle tertile	0.38* (0.15–0.97)	0.31* (0.11–0.86)	1.23 (0.61–2.47)	1.05 (0.46–2.40)
Highest tertile	1.58 (0.53–4.67)	0.86 (0.23–3.21)	2.95** (1.34–6.51)	1.31 (0.45–3.80)
No. of gates/barrier				
Lowest tertile	1.0	—	1.0	—
Middle tertile	0.58 (0.25–1.38)	—	0.56 (0.28–1.14)	—
Highest tertile	1.71 (0.57–5.08)	—	1.11 (0.51–2.41)	—
No. of “slow points”/road narrowing				
None	1.0	—	1.0	—
At least one	0.52 (0.24–1.16)	—	1.45 (0.76–2.78)	—
No. of traffic/pedestrian lights				
Lowest tertile	1.0	1.0	1.0	1.0
Middle tertile	2.28 (0.85–6.15)	2.52 (0.83–7.59)	3.22** (1.52–6.87)	2.74* (1.21–6.19)
Highest tertile	2.98* (1.22–7.24)	2.22 (0.71–6.92)	4.98*** (2.28–10.88)	2.62 (0.96–7.13)

*Denotes $p < 0.05$ **Denotes $p < 0.01$ ***Denotes $p < 0.001$ ^aMultiple logistic regression including all variables with significant bivariate associations

girls, the number of traffic/pedestrian lights remained significantly negatively associated with their MVPA on weekends. The model was significant ($p = 0.014$) and explained 14% of the variance.

Significant associations between road environment measures and MVPA for adolescents are shown in Table 5. For adolescent boys, residing on a cul-de-sac, compared with a through road, was associated with increases in MVPA of around

TABLE 4 Unadjusted and adjusted regression analyses of road environment measures and MVPA among children

Accelerometer data (min)	Younger boys			Younger girls		
	Unadjusted <i>B</i>	Adjusted ^a <i>B</i>	Adjusted ^a beta	Unadjusted <i>B</i>	Adjusted ^a <i>B</i>	Adjusted ^a beta
MVPA before school						
Total length of local roads (km)	—	—	—	−0.614**	Not entered	Not entered
Total no. of intersections	—	—	—	−0.068*	—	—
MVPA on weekend day						
Total length of local roads (km)	−4.376*	Not entered	Not entered	—	—	—
Total no. of intersections	−0.693***	−0.493*	−0.262*	−0.423*	0.047	0.027
Total length walking tracks (m)	−0.025*	−0.023*	−0.235*	−0.025*	−0.014	−0.142
Total traffic/pedestrians lights	−8.052***	−3.565	−0.156	−8.218**	−7.415*	−0.312*

Table shows significant associations ($p<0.05$) only
Not entered Not used in the adjusted regression due to a variance inflation factor>2.0 and a lower adjusted beta value than the variable with which it was correlated
*Denotes $p<0.05$
**Denotes $p<0.01$
***Denotes $p<0.001$
^aMultiple linear regression including all variables with significant bivariate associations

9 min after school, 5 min in the evening, and 22 min on weekend days. In multiple regression analyses, “residing on a cul-de-sac” and number of speed humps remained significantly associated with boys’ MVPA during evenings, with the model explaining 11% of the variance.

DISCUSSION

This study sought to examine associations between the local road environment and physical activity among youth. The hypothesis that the presence of road environmental measures related to safety in children’s neighborhoods is associated with increased habitual walking/cycling and MVPA outside school hours is supported by these results for adolescents; however, the road environment was an important predictor of habitual walking/cycling among girls and of MVPA among boys. By contrast, the hypothesis was not supported for children. In fact, among children, the findings were either null or in the opposite direction to those hypothesized, with MVPA on weekends negatively associated with total length of walking tracks and numbers of intersections and traffic/pedestrian lights. This research is important for informing efforts to create “child-friendly” neighborhoods

TABLE 5 Unadjusted and adjusted regression analyses of road environment measures and MVPA among adolescents

Accelerometer data (min)	Adolescent boys			Adolescent girls		
Road characteristics	Unadjusted <i>B</i>	Adjusted ^a <i>B</i>	Adjusted ^a beta	Unadjusted <i>B</i>	Adjusted ^a <i>B</i>	Adjusted ^a beta
MVPA before school						
Total no. of speed humps	—	—	—	−0.073*	—	—
MVPA after school						
Reside in a cul-de-sac	8.566*	—	—	—	—	—
MVPA in evening						
Reside in a cul-de-sac	4.797*	5.453**	0.231**	—	—	—
Total no. of speed humps	0.210*	0.189**	0.250**	—	—	—
MVPA outside school hours						
Total length of walking tracks (m)	—	—	—	0.004*	—	—
Reside in a cul-de-sac	10.12*	—	—	—	—	—
MVPA on weekend days						
Reside in a cul-de-sac	21.739*	19.814	0.171	—	—	—
Total no. of slow points	−5.197*	−4.720	−0.168	—	—	—

Table shows significant associations ($p < 0.05$) only

*Denotes $p < 0.05$

**Denotes $p < 0.01$

***Denotes $p < 0.001$

^aMultiple linear regression including all variables with significant bivariate associations

and guide environmental interventions aimed at increasing physical activity by improving the safety of local streets.

For adolescent girls, there were strong associations between objective road environmental measures and walking/cycling. In particular, the presence of traffic/pedestrian lights was positively associated with habitual walking and cycling. These associations are supported by earlier findings that walking for exercise and transport by adolescent girls were positively associated with girls' perception that local roads were safe.¹⁹ The negative association between girls' habitual walking/cycling and residing on a cul-de-sac aligns with literature on adults' walking, where cul-de-sacs are indicative of low street connectivity which may not be conducive to active transport.²⁹ By contrast, adolescent boys' MVPA was significantly increased after school, in the evenings, and on weekends if they resided on a cul-de-sac. Possibly, these boys engaged in informal MVPA such as football or skateboarding in the cul-de-sacs, while girls did not engage in MVPA there. The findings for boys are more consistent with others from studies of younger children, rather than adolescents, which show that parents consider cul-de-sacs to be safe play venues³⁰ and that

children who reside on cul-de-sacs play outdoors more frequently than those who reside on through roads.³³

This study's other key finding was the positive association between the presence of speed humps and MVPA among adolescent boys during evenings. This result is consistent with findings of a Californian study that the odds of a child being injured or killed when struck by a motor vehicle were reduced by around 60% if a speed hump was located within a block of the child's home.²² Furthermore, traffic-calming interventions in the Netherlands are associated with low child pedestrian injury rates^{34,35} and high participation rates in active transport.³⁶ Together with the result presented here, these studies indicate that traffic calming may be an important road safety measure that promotes physical activity. A Department of Transport report,³⁷ however, emphasizes the importance of careful design of traffic-calming measures. While discomfort when crossing speed humps may inadvertently discourage cyclists, this may be avoided by leaving a suitable gap between the end of a speed hump and the kerb to allow bicycle access. Perception of discomfort when cycling may have contributed to the negative association between speed humps and habitual walking/cycling among adolescent boys.

In this study, different associations were found for the two outcome variables, namely, habitual walking/cycling versus overall MVPA. These distinct findings highlight the need to examine "behavior-specific" environmental measures as predictors of "context-specific" behaviors, as argued by Giles-Corti et al.³⁸ While the accelerometer is recognized as a powerful tool for measuring overall physical activity,³⁹ the MVPA recorded may have taken place outside the neighborhood. Conversely, road environment measures were collected only from participant's immediate neighborhoods, providing data directly relevant to behaviors occurring specifically within this context, such as walking/cycling.

The null and negative findings between the road environment and children's walking/cycling, and MVPA are difficult to explain. Although this study examines MVPA during periods with opportunities for activity within local neighborhoods, a limitation is that the exact location of any MVPA is unknown. As Karsten⁴⁰ reports, many children now belong to the "backseat generation", being driven to structured leisure-time activities outside the neighborhood. Such activities would not be influenced by the local road environment and could potentially explain null associations between some road environment measures and children's physical activity.

Furthermore, it is important to note that this study focused only on objective features of the road environment and did not examine other objective measures which may also influence MVPA and walking trips, such as the proximity of shops, parks, and recreational facilities. Parents' or children's perceptions of the road environment may differ to these objective estimates, while the road features examined here may influence parents' perceptions of other aspects of safety. For example, the presence of many traffic/pedestrian lights may heighten the perception of heavy traffic and lead to reductions in walking/cycling or physical activity within the neighborhood. This may be particularly salient considering that children's behaviors may be strongly controlled by their parents, while adolescents' physical activity and use of the neighborhood may be greater due to increased autonomy and ability to deal with their environments.^{3,12} This could potentially explain negative associations between some road environment measures and children's physical activity. Valentine¹² argues that as children approach adolescence, they may be granted greater independent mobility beginning with the transition from junior to senior school. At this time, they may have to travel further than before, possibly by

public transport, and may engage in different social activities which encourage increased independence.¹²

This study is among the first to examine associations between objective measures of the road environment and physical activity among youth. Its strengths are the inclusion of a large sample of children and adolescents living in diverse neighborhoods, use of accelerometry to objectively assess physical activity outside of school hours, and use of GIS technology to objectively measure the road environment. Although limited by its cross-sectional design, this study is also strengthened by the inclusion of data about boys and girls in two distinct age groups. The findings indicate that the local road environment may influence the physical activity of children and adolescents in different ways. Further research should examine the relative influence of perceived and objective measures of road safety on children's physical activity and the influence of social incivilities (e.g., crime) and personal safety. Using GIS technology, the proximity of destinations of interest to young people such as shops, parks, and recreational areas should be examined in relation to MVPA. Future studies should be longitudinal to determine causality and may help inform policy-makers and urban planners. As yet, it is unclear if interventions to increase physical activity among youth in the neighborhood should focus on altering the physical environment or improving perceptions of safety there (or both).

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