087

The effects of perceived and objective measures of home-environment on transportation and recreational walking among children

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Abstract

This study explores the relative association of objective and perceived environmental factors with recreational and transportation walking behaviour. Randomly selected parents of students (ages 12-14) at 10 elementary schools (N=1000) located in Istanbul, Turkey, completed questionnaires about their socio-demographic characteristics, neighbourhood environment, and their children's physical activity.

Home-environments (400 and 800 meter buffers) were evaluated through GIS-based land-use, segment-based street connectivity measures, and street-level topography. In addition, detailed field surveys related to pedestrian quality attributes were conducted within home-environments. Logistic regression was used to investigate the relationships between recreation and transportation-related walking and objective and perceived measures of the built form.

Findings of the study indicate that both types of walking behaviour are associated with different perceived and objective environmental attributes. More importantly, preliminary results suggest street network connectivity measured at the segment-level is significantly associated with walking behaviours. Thus, it can be argued that modifications to the home-environment may help change hence children's walking behaviour.

Keywords

Walking behaviours, street connectivity, objective and perceived environmental measures, home-environment, Istanbul.

1. Introduction

Rapidly sprawling cities with fragmented land-uses and discontinuous street networks hinder children-oriented transportation modes of travel. Studies on children's commuting patterns to schools have shown a decline in active commuting levels not only in suburbs but also in urban areas across different countries. Walking for both recreational and transportation purposes may significantly contribute to children's daily physical activity levels, thus help prevent obesity in children. Active living and childhood obesity have become national priority in Turkey (Healthy Eating and Active Living Program 2010-2014), along with the current pedestrianization projects of particularly older districts (Labkultur, 2013; Oztas and Aki, 2014) ,but there is lack of data on pedestrian movement, most particularly on children's mode of transportation between home and school.

Studies investigating the specific relationship between walkability and children's active travel follow two lines of inquiry. The first group of studies focuses on physical environment's characteristics in affecting children's active commuting (Moudon and Lee, 2003; Panter et al., 2010). The main theme of this research is that the distance between home and school (Schlossberg et al., 2006) and traffic density (Davison and Lawson, 2006) to be negatively associated with children's active commuting while the availability and conditions of sidewalks as well as the presence of controlled crossings (Boarnet et al., 2005) and mixed land-use around the school (Kerr et al., 2007) are associated with increased walking. However; few studies have evaluated different types of walking (i.e. recreational vs. transportation) (Pikora et al., 2003; Troped et al., 2003). As existing research indicates that specific environmental attributes associated with different purposes of walking tend to differ (Pikora et al., 2003; Troped et al., 2003) failure to consider them separately may result in biased outcomes. In addition, since most studies have assessed the environmental determinants of adults' active travel, research in understanding the factors associated with children's active travel is limited (Giles-Corti et al., 2009).

The second group of studies explore the different associations of objective and perceived walkability with active travel. Findings show that both contribute to the amount of walking (Arvidsson et al., 2012; McGinn et al., 2007), but the strongest association of the built environment on active travel is achieved when these are in correspondence (Gebel et al., 2011). Among adults, the perceived presence of sidewalks, aesthetics, and accessibility to facilities are shown to be positively associated with active travel (Duncan et al., 2005; Hoehner et al., 2005). Similarly, parental perceptions of the built environment are shown to be predictors of active commuting behaviour in children (Lee et al., 2013; Panter et al., 2010). However; few studies have simultaneously assessed parental perceptions and objective measures of the built environment in affecting children's pedestrian behaviour (Timperio et al., 2006). Parental safety concern is negatively associated with children's walking levels (Timperio, 2004), whereas perceived presence of facilities are associated with increased likelihood of walking (Kerr et al., 2006)

Particularly in the last decade, researchers have focused on the importance attributed to street network design. Empirical evidence shows that reduced size of street blocks or the presence of a fine-grained urban network of densely interconnected streets can promote higher proportion of walking, more walk trips, and longer trips (Kerr et al., 2007; A. Moudon et al., 2006; Saelens et al., 2003). Despite recent efforts, the effect of street network configuration on overall travel remains unclear. One reason is the absence of measures that can systematically characterise the spatial structures of urban street networks at various scales and hierarchies. The significance of spatial structure in affecting pedestrian movement has been addressed through the framework of configurational analysis of space syntax. Earlier studies have shown that road segments that are accessible from their surroundings with fewer direction changes tend to attract higher flows (Hillier et al., 1993; Peponis et al., 1997). Recent research has demonstrated street network design to be significantly related to recreational (Lee and Moudon, 2006) as well as transportation walking behaviours (Ozbil and Peponis, 2012).

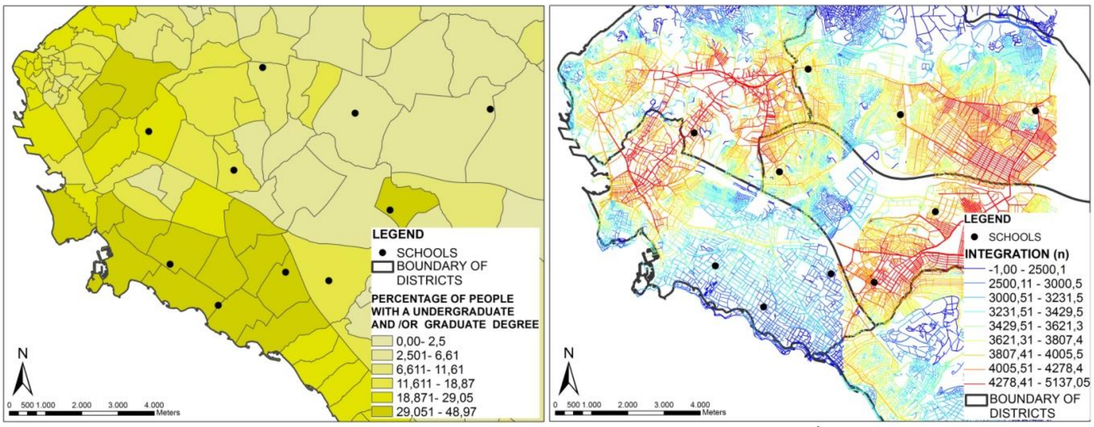
This study contributes to the literature by combining both lines of inquiry to address the limitations reviewed above. This paper focuses on the relationship between children's physical activity levels – measured in terms of recreational and transportation walking patterns– and the environmental characteristics of the home-environment –measured through parental perceptions and objective street-level data, including systematically assessed spatial network configuration. The primary aim is to determine the relative association of perceived and objective environmental factors with recreational and transportation walking behaviour, controlling for personal and socio-demographic characteristics.

2. Methods

Study Population

Data for this cross-sectional study were drawn from questionnaires conducted in 10 elementary schools located in Istanbul, Turkey, in districts chosen for their variability in education levels and spatial structure of street networks (Figure 1) as well as their locations within the city (Figure 2). Kadıköy and Üsküdar are central-city districts, while Ataşehir and Ümraniye are contemporary suburban and peripheral districts respectively. The underlying reason for studying the Anatolian part is due to the different urban patterns dominating each continent. The European part is mostly dominated by high-rise mass housing, service and commercial land-uses, whereas the Anatolian part reflects mostly a residential character with mixed land-uses prevailing the central parts. Although the selected areas represent a small cross-section of the entire city, the sum of their population equals to one-sixth of Istanbul's total population.

Questionnaires were completed by parents of randomly selected 6th, 7th, and 8th grade students (ages 12-14[1]) between May and December 2014 (N=1000). This age group represents the upper-elementary school students, who are arguably more conscious of their travel choices. The return rate was %59. Respondents with missing data for children's activity types (*n*=30) were excluded from the analyses. The home addresses of the final set of respondents were geocoded onto Census TIGER/line road files (N=504).



a. b.

Figure 1: Locations of surveyed schools. Maps are colored based on (a) the neighborhood-based average education percentages[2], and (b) global Integration[3] values of the street network.

Field Audits

Field audits were conducted within 800meter buffers around the respondents to assess the street-level accessibility and pedestrian quality. Due to resource limitations, only 40 street segments within 1600m-radius of each school were audited. The selection of audited street segments were based on three criteria: (1) within walking distance (1600m) of the surveyed schools, (2) not a dead-end street, (3) local streets with maximum posted speed limit of 50 km/hour[4]. These sampling criteria ensured consistency among the sampled segments in terms of the overall pedestrian facilities. Based on these criteria, audited-segments were selected to include street-segments with differing structural levels (Figure 3). Home-environments in which the total length of audited segments was ≤%10 of average total segment length within their buffers were excluded from the dataset (*n*=190). The remaining 314 home-environments were included in the analysis.

[1] Note: Some students with exceptional ages of 11, 15, and 16 studying in these grades were also included in the analyses.
[2] 2014 neighborhood-level education data was provided by TÜİK (Turkish Statistical Institute).
[3] Integration measures how accessible each space is from all the others within the radius using the least angle measure of distance.
[4] Home-environments used in the analyses mostly did not include heavy-traffic roads in their buffers. Hence, traffic data were not included as audit measure.

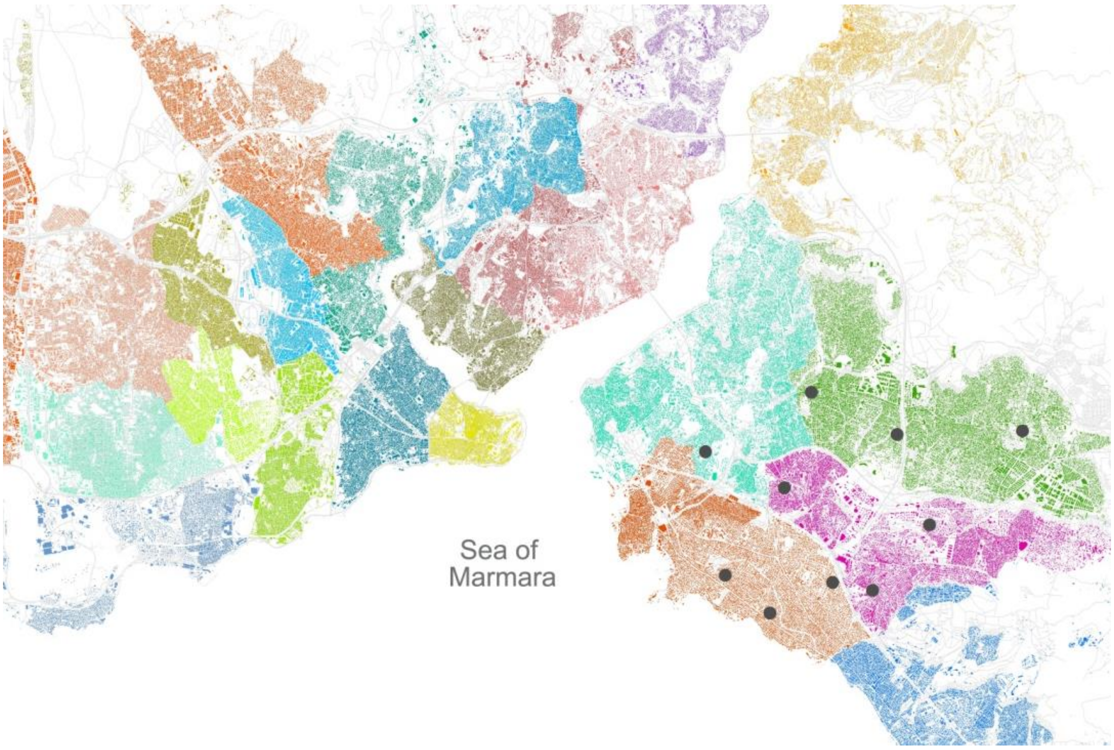
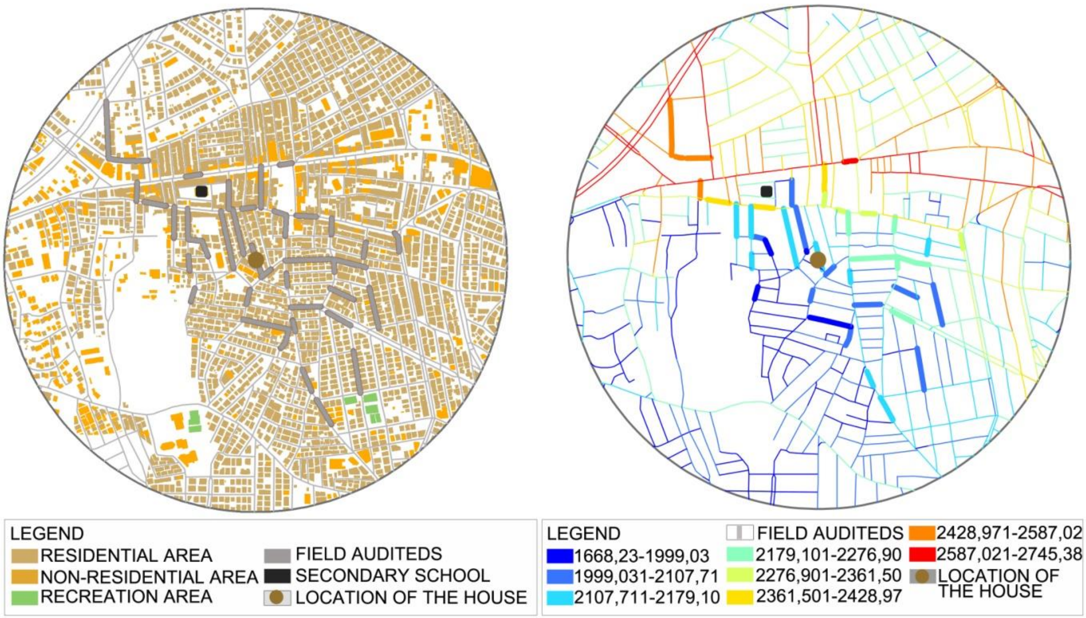


Figure 2: Locations of surveyed schools. Map is colored based on the boundary of districts of Istanbul



a. b.

Figure 3: Distribution of audited street segments within the home-environment (800m-radius) represented by (a) parcel-level land-uses, and (b) global Integration values of the street network.

Instrumentation and Measures

Walking Behaviour

Parents reported their child's main mode of transport between home and school as well as the frequency of recreational and transportation walking during a typical day in their neighbourhood.

Perceived Environmental Measures

The questions selected for measuring parents' perceptions of their home-environment were drawn from the *NEWS* (Cerin et al., 2006) which assesses socio-demographic characteristics as well as the perception of neighbourhood design features related to physical activity, including street connectivity, infrastructure for walking, neighbourhood aesthetics, and traffic safety. Parental perceptions were analysed in 6 categories: accessibility, land-use, street connectivity, aesthetics, recreational facilities and safety. Survey questions used Likert-type response categories (strongly agree, agree, neutral, disagree, and strongly disagree).

Objective Environmental Measures

Home-environments (400 and 800meter buffers around the respondent) were evaluated through GIS-based measures. Parcel-level land-use densities were summarized for each buffer using 2014 GIS-based land-use data provided by the Municipality. Street-level topography was assessed by calculating the average percent slope for each segment within the study areas. Environmental audit items were selected following review of prevalent measures used in the literature (Hoehner et al., 2005; Zhu and Lee, 2008). Audit-derived environmental measures used for this analysis were grouped into 4 categories: accessibility, aesthetics: recreational facilities, and safety. The measures are described in Table 1. These measures were used to complement the land-use measures in describing the pedestrian quality of home-environments. Clearly, the extent to which the perceived and objective measures capture similar environmental characteristics varies, since some measures are more directly comparable (i.e. non-residential destinations, public transport[5]) than others (i.e. street connectivity, aesthetics).

Street network configuration within home-environments was quantified using two different descriptors of spatial structure of street networks based on 2014 ESRI Streetmap provided by the Municipality. *Segment Angular Integration* measures how accessible each space is from all the others within the radius using the least angle measure of distance. *Segment Angular Choice* which measures the extent to which a node is located in between the paths connecting all pairs of origins and destinations (Hillier and Iida, 2005). These two measures represent the *to* and *through* movement potential of the street segment (Hillier et al., 2012). Choice and Integration (radius 3, n) for both 400 and 800meter radii were calculated. Average *Connectivity* within buffers was also included in the analysis to measure the extent to which each space is connected locally.

Table 1. Summary of Measures.

Perceived Measures	Description	Objective Measures	Description
Accessibility			
sidewalk availability	There are sidewalks on most streets in my community.	Field-audit: segments with sidewalks on both sides	Percent of street segments with sidewalks on both sides
İntegration within urban environment	My neighbourhood is integrated with its local urban context.	Integration (r:3, n)	avg. depth of each street segment from all others in terms of min. number of direction changes
public transport availability	Public transportation network in this neighbourhood provides easy access to other parts of the city.	Segments with a bus stop	Percent of street segments with a bus stop

[5] Location of bus stops and schools were geocoded on GIS using GoogleEarth and actual addresses respectively.

Accessibility to public transport	It is easy to walk to a bus stop from my home.	Distance to nearest bus stop	Straight-line distance from respondent's home to the nearest bus stop
Topography	The neighbourhood has steep slopes which hinders walking.	Avg. percent of slope	Avg. percent of slope of street segments
Land-use			
availability of destinations within walking distance	There are many destinations within walking distance from my home.	total land-use density	total area of uses, averaged by buffer
availability of stores within walking distance	There are many destinations within walking distance from my home.	non-residential land-use density	total area of non-residential destinations, averaged by buffer
Street Connectivity*			
avg. block-face length	Distance between street intersections is generally short (<100 mt).	Connectivity	the number of segments directly connected to each segment in the network
		Integration (r: 3, n)	the smallest number of links from a segment to all other segments
alternative routes	There are alternative routes between origin and destination pairs in the neighbourhood.	Choice (r: 3, n)	the proportion of shortest paths between origin-destination pairs that pass through each segment
Aesthetics			
Neighbourhood pleasant	There are many interesting architectural sights in my neighbourhood.	Field audit: segments with landmarks	Percent of street segments with landmarks
Neighbourhood pleasant	There are many interesting natural sights in my neighbourhood.	Recreational use density	Total area of parks within buffers
Trees along neighbourhood streets	There are trees along the streets in my neighbourhood.	Field-audit: segments with trees	Percent of tree-aligned street segments
Sidewalks well-maintained	Streets within this neighbourhood are well maintained.	Field-audit: quality of street segments	Percent of street segments with moderate-to-high quality (minimal cracks, heaves, etc.)
Recreational Facilities			
Many parks in the neighbourhood	There is no park within walking distance from my home.	Recreational use density	total area of parks within buffers
Safety			
Feel safe from traffic	Sidewalks are separated from streets through a buffer zone.	Field audit: segments with buffers	Percent of street segments with any type of buffer
Feel safe from traffic	There are no parked cars on the sidewalks that hinder walking.	Field audit: segments with cars parked on sidewalk	Percent of street segments with cars parked on sidewalk on any side

Strong concern about road safety	There is adequate number of crossing-aids for pedestrians in my community.	Field-audit: segments with a crossing-aid	Percent of segments with a traffic-crossing or traffic signal

Survey response categories include; strongly disagree, disagree, undecided, agree, strongly agree.
* Survey measures of street connectivity did not correspond fully to objective segment-based measures but were approximations of the connectivity patterns intended to be measured.

3. Data Analysis

Logistic regressions[6] were estimated separately to assess how the perceived and objective environmental attributes relate to recreational and transportation walking separately. Changes in the patterns of walking behaviour by each set of measures were compared through odds ratios (ORs) and 90% confidence intervals (CIs). Categories hypothesized to be negatively associated with walking (disagree/strongly disagree) were assigned as the reference category for all perceived measures. Simple correlations were run among measures to check for association, and those with problematic multicollinearity ($r^2 \geq 0.70$) were not included in the models simultaneously. All regression analyses were performed separately for each environmental category (i.e. accessibility), controlling for student's gender and age as well as car ownership[7], household income[8], and parental education[9]. The Student's T-test was used for comparing the average global Integration (800m) ($r^2=0.99$, $p<0.01$) and Choice (800m) ($r^2=0.75$, $p<0.01$) values across school-environments. The results clearly demonstrate the variability of street network connectivity patterns.

4. Results

Tables 2 and 3 present the associations of the perceived environmental measures (left 3 columns) and the corresponding objective measures –GIS-based and audit-based– (right 3 columns) with recreational and transportation walking respectively. All variables reported in the tables are for 800meter buffers, if not reported otherwise.

Associations with Recreational Walking

Recreational walking was measured using two dichotomous independent variables. "Any recreational walking" measured engaged in any (i.e. walking the dog) versus no recreational walking. "Any recreational walking (met PA level)" measured recreational walking ≥30 minutes/day, meeting daily recommended moderate physical activity level, versus recreational walking for lower durations. Parental education level was significantly associated with both types of recreational walking. Students whose parent(s) held a college or upper degree were more likely to engage in any type of recreational walking and meet recommendations through recreational walking. No other associations were observed from the socio-demographic measures.

For both types of recreational walking, the integration of home-environment with its surroundings was significantly and positively associated with perceived and objective accessibility measures. Students whose parents strongly agreed that their home-environment was locally integrated were 1.6 times more likely to meet physical activity recommendations through recreational walking compared to those whose parents strongly disagreed. The corresponding objective variable global Integration within 800meter was also significantly associated with recreational walking, but with a weaker effect size.

Associations between land-use measures and recreational walking were only statistically significant for the objective GIS-based measure of the density of total destinations within a 400meter radius.

[6] Logistic regression allows for estimating multiple parameters of a binary categorical dependent variable.
[7] total number of cars owned by the household
[8] monthly salary per household
[9] either/both of parents holding a college and/or an upper-level degree vs.both parents holding a lower-level education degree

This suggests that increasing land-use density within a 5-minute walking distance of homes would slightly increase the odds of recreational walking to meet healthy living guidelines.

Both the perceived and objective measures related to street network connectivity showed positive and significant relationships with recreational activity. Engaging in any type of recreational walking and meeting recommendations through recreational walking were significantly associated with parents perceiving the average distance between intersections to be less than 100meter in the neighbourhood. This was consistent with the corresponding objective measure global Integration, which showed slightly significant and positive associations with both types of recreational walking. Students whose parents strongly agreed that many alternative routes were present between origin and destination pairs were three times more likely to walk for any type of recreation purposes. Global Choice and Connectivity measures were not significant.

For aesthetics, only the audit measure for the presence of tree-aligned streets was associated with more recreational walking, with each additional percent of tree-aligned street in the neighbourhood increasing the odds of recreational walking by 1%. No significant associations were observed for the existence of recreational uses. Engaging in any recreational walking was significantly associated with the parental perception of the prevalence of crossing aids along the streets in their community; however, it was not associated with the corresponding objective measure.

Table 2. Associations between perceived and objective environmental measures and recreational walking within home-environments.

Recreational walking

	Perceived	**Any Recreational walking[a] aOR (%90 CI)**	**Recreational walking (met PA level)[b] aOR (%90 CI)**	**Objective**	**Any Recreational walking[a] aOR (%90CI)**	**Recreational walking (met PA level)[b] aOR (%90 CI)**
Socio-demographics				Student's Gender		
				Male	0.89 (0.54-1.48)	0.93 (0.53-1.64)
				Student's Age		
				16	1.00	1.00
				15	0.00 (0.00-11.12)	0.00 (0-6.54)
				14	0.00 (0-12.41)	0.00 (0-8.67)
				13	0.00 (0-15.48)	0.00 (0-10.92)
				12	0.00 (0-11.72)	0.00 (0-8.62)
				11	1.15 (0-)	1.33 (0-)
				Parental Education (college degree)		
					1.65 (0.91-2.96)**	**1.43(0.78-2.62)*****
				Car ownership		
					0.90 (0.63-1.28)	0.53 (0.10-2.55)
Accessibility	Sidewalks present			Segments with sidewalks on both sides		
	SD	1.00	1.00		0.96 (0.93-1.02)	0.98 (0.93-1.03)
	D	0.78 (0.42-1.44)	0.71 (0.34-1.53)			
	N	0.52 (0.22-1.23)	0.47 (0.18-1.25)			
	A	0.78 (0.31-1.97)	0.75 (0.27-2.24)			
	SA	0.57 (0.18-3.18)	0.85 (0.17-6.28)			
	Existence of slopes			Average slope within buffer		
	SD	1.00	1.00		0.57 (1.13-1.76)	0.81 (0.40-1.70)
	D	1.15 (0.53-2.53)	1.29 (0.54-3.06)			
	N	**2.94 (1.15-7.93)****	**2.47 (0.88-7.40)***			
	A	1.21 (0.55-2.67)	1.89 (0.76-4.77)			
	SA	1.62 (0.68-3.89)	1.61 (0.64-4.09)			
	Neighbourhood integrated within urban context			Global Integration		
	SD	1.00	1.00		**1.01 (1.00-1.00)****	**1.01 (0.93-1.03)****
	D	1.68 (0.86-3.33)	**2.03 (0.98-4.31)****			
	N	1.04 (0.48-2.25)	**2.00 (0.84-5.05)***	Connectivity		
	A	**2.07 (0.88-5.13)***	2.08 (0.84-5.58)		1.50 (0.25-9.44)	0.41 (0.08-1.53)

	SA	**2.56 (0.88-8.66)***	**3.58(1.04-16.86)****		
Land-Use	Many stores within walking distance			Avg. non-residential land-use density (400m)	
	SD	1.00	1.00	1.00 (1.00-1.00)	1.00 (1.00-1.00)
	D	1.00 (0.49-2.01)	0.86 (0.39-1.88)		
	N	0.65 (0.20-2.10)	0.98 (0.27-4.01)		
	A	0.89 (0.36-2.50)	1.20 (0.43-3.77)		
	SA	0.84 (0.29-2.56)	0.90 (0.29-3.20)		
	Many destinations within walking distance			Avg. total land-use density (400m)	
	SD	1.00	1.00	**1.01 (1.00-1.00)****	**1.01 (1.00-1.00)****
	D	1.18 (0.60-2.33)	1.23(0.57-2.67)		
	N	1.96 (0.71-5.98)	1.32 (0.43-4.52)		
	A	1.97 (0.71-5.93)	1.98 (0.63-7.11)		
	SA	1.15 (0.35-4.24)	1.33 (0.35-6.62)		
Connectivity	Distance between street intersections short			Global Integration	
	SD	1.00	1.00	**1.01 (1.00-1.00)****	**1.01 (1.00-1.00)***
	D	1.26 (0.49-3.18)	1.46 (0.53-3.91)	Connectivity	
	N	1.22 (0.48-3.00)	1.71 (0.63-4.50)	0.62 (2.18-1.61)	0.38 (0.10-1.49)
	A	**2.82 (0.97-8.42)***	**3.41(1.05-11.52)****		
	SA	1.17 (0.28-5.48)	1.05 (0.24-4.99)		
	Many alternate routes present between nodes			Global Choice	
	SD	1.00	1.00	1.00 (1.00-1.00)	1.00 (1.00-1.00)
	D	1.48 (0.78-2.80)	1.17 (0.55-2.44)		
	N	1.90 (0.86-4.31)	1.58 (0.61-4.25)		
	A	1.17 (0.54-2.61)	0.68 (0.28-1.65)		
	SA	**3.06 (0.89-14.31)***	1.19 (0.31-5.90)		
Aesthetics	Many unique buildings present along routes			Segments with landmarks	
	SD	1.00	1.00	1.01 (0.95-1.08)	1.02 (0.99-1.02)
	D	0.58 (0.19-1.60)	0.56 (0.18-1.78)		
	N	0.55 (0.18-1.42)	0.74 (0.22-2.21)		
	A	0.65 (0.22-1.76)	0.68 (0.21-1.91)		
	SA	0.71 (0.44-2.68)	0.75 (0.20-2.61)		
	Many landscape elements present along routes			Avg. density of recreational use	
	SD	1.00	1.00	1.00 (1.00-1.00)	1.00 (1.00-1.00)
	D	1.21 (0.24-5.14)	1.22 (0.24-5.51)		
	N	0.97 (0.21-4.10)	1.89 (0.39-8.89)		
	A	1.48 (0.31-5.91)	2.18 (0.48-9.92)		
	SA	0.83 (0.17-3.63)	0.98 (0.19-4.61)		
	Sidewalks maintained			Streets with minimal problems (heaves, cracks, etc.)	
	SD	1.00	1.00	0.99 (0.98-1.01)	1.00 (0.98-1.01)
	D	0.73 (0.28-1.80)	0.69 (0.21-1.59)		
	N	0.66 (0.23-1.77)	0.94 (0.26-2.47)		
	A	0.50 (0.18-1.28)	0.54 (0.18-1.52)		
	SA	0.94 (0.30-2.81)	1.15 (0.30-3.56)		
	Presence of tree-aligned streets			Segments with trees	
	SD	1.00	1.00	**1.01 (1.00-1.02)***	**1.01 (1.00-1.02)***
	D	1.10 (0.51-2.69)	1.39 (0.60-3.66)		
	N	1.62 (0.68-4.28)	1.51 (0.54-4.22)		
	A	1.14 (0.61-3.87)	1.28 (0.51-3.76)		
	SA	0.99 (0.34-2.91)	1.17 (0.37-3.84)		
Recreation	Many recreational uses			Avg. density of recreational use	
	SD	1.00	1.00	1.00 (1.00-1.00)	1.00 (1.00-1.00)
	D	1.36 (0.48-2.51)	1.65 (0.87-3.20)		
	N	0.83 (0.48-2.51)	1.16 (0.49-2.92)		
	A	1.29 (0.52-3.42)	1.19 (0.55-2.87)		
	SA	1.76 (0.27-2.24)	1.28 (0.46-2.62)		
S	Crosswalks and traffic lights present			Segments with crosswalks/traffic lights	

	SD	1.00	1.00		1.01 (1.00-1.02)	1.01 (0.98-1.02)
	D	1.83 (0.73-3.71)	1.87 (0.64-3.83)			
	N	1.82 (0.71-3.91)	1.43 (0.50-3.12)			
	A	**2.08 (0.86-5.10)***	2.06 (0.71-4.74)			
	SA	2.05 (0.79-5.42)	1.81 (0.60-4.41)			
	Buffers present along sidewalks			Segments with buffers		
	SD	1.00	1.00		1.00 (0.97-1.05)	1.01 (0.97-1.04)
	D	1.24 (0.42-3.40)	0.94 (0.36-3.32)			
	N	1.26 (0.41-2.82)	1.18 (0.43-3.28)			
	A	1.99 (0.69-4.47)	2.14 ()0.77-5.74			
	SA	1.96 (0.58-4.17)	1.87 (0.57-4.78)			
	Parked cars on sidewalks			Segments with no cars parked on sidewalk		
	SD	1.00	1.00		1.00 (0.98-1.01)	1.00 (0.98-1.01)
	D	2.18 (0.42-8.05)	3.35 (0.58-16.73)			
	N	0.65 (0.14-2.73)	0.81 (0.13-3.18)			
	A	1.41 (0.28-5.11)	1.17 (0.17-3.82)			
	SA	1.38 (0.32-5.15)	1.56 (0.31-6.38)			

*p≤0.10; **p≤0.05; ***p≤0.01; N=314

SD: Strongly Disagree; D: Disagree; N: Neutral; A: Agree; SA: Strongly Agree

aOR: adjusted Odds Ratio; CI: Confidence Interval

All measures are for 800 meter buffers, if otherwise not reported.

[a] engaged in any versus no type of recreational walking

[b] Recreational Walking ≥30 minutes/day, meeting moderate Physical Activity level, versus recreational walking for lower durations.

Associations with Transportation Walking

Two dichotomous independent variables were developed for measuring transportation walking. “Any transportation walking” measured engaged in any versus no transportation-related walking.

“Active Commuting” measured the combination of any transportation walking and always/frequently walking to/from school. Socio-demographic measures did not indicate any association with transportation walking. While students whose parents agreed that there were sidewalks on the majority of streets were more likely to engage in any transportation walking, children whose parents were neutral with regard to the presence of sidewalks were more likely to walk both for transportation purpose and to/from school than those whose parents strongly disagreed. The perceived accessibility to bus-stops indicated a significant and positive association with active commuting, but there were no significant associations with the corresponding measure. The only objective variable significantly associated with transportation walking was local Choice within 400meter.

Children whose parents had access to more destinations within a 10-minute walking distance of their homes were more likely to engage in any type of transportation activity and walking to/from school, compared to those whose parents lived in lower land-use density communities.

The only association observed between the survey measures for street connectivity and transportation walking was the perceived prevalence of alternative routes in the neighbourhood. Children whose parents were neutral with regard to the presence of alternative routes between origin-destination pairs were more likely to walk engage in active commuting than those whose parents strongly disagreed. The corresponding objective measure local Choice showed significant and positive association with the same outcome.

Perceived presence of interesting architectural sights and landscaping along routes was positively and significantly associated with active commuting. Similarly, children whose parents strongly agreed that there were tree-aligned streets within the community were more likely to engage in transportation walking, than those whose parents strongly disagreed. No associations were observed from the objective measures.

Children whose parents strongly agreed that crosswalks/traffic lights were present within their community were three times more likely to engage in walking for transportation, compared to those whose parents strongly disagreed. Perceived presence of parked cars on sidewalks indicated a negative and significant association with transportation walking. Neither of the corresponding objective measures was correlated with this outcome.

Table 3. Association between perceived and objective environmental measures and transportation walking within home-environments.

	Transportation walking					
	Perceived	**Any Transportation walking[c] aOR (%90 CI)**	**Active Commuting[d] aOR (%90 CI)**	**Objective**	**Any Transportation walking[c] aOR (%90 CI)**	**Active Commuting[d] aOR (%90 CI)**
Socio-demographics				Student's Gender		
				Male	1.10 (0.67-1.80)	0.93 (0.53-1.64)
				Student's Age		
				16	1.00	1.00
				15	3577320 (0.39-)	0.00 (0-143.20)
				14	2910311 (0.33-)	0.00 (0-159.65)
				13	2308414 (0.26-)	0.00 (0-121.50)
				12	1576390 (0.17-)	0.00 (0-79.52)
				11	1234658 (0.06-)	1.62 (0-)
				Parental Education (college degree)		
					1.11 (0.62-2.07)	1.12(0.35-3.10)
				Car ownership		
					0.71 (0.50-1.01)	0.76 (0.06-8.10)
Accessibility	Sidewalks present			Segments with sidewalks on both sides		
	SD	1.00	1.00		1.00 (0.95-1.05)	0.98 (0.90-1.06)
	D	1.37 (0.70-2.32)	0.61 (0.19-1.84)			
	N	1.98 (0.74-4.21)	**6.37(0.74-151.66)***			
	A	**2.69 (1.02-7.81)****	2.88 (0.37-63.30)			
	SA	2.07 (0.48-11.01)	0.94 (0.09-25.33)			
	Existence of slopes			Average slope within buffer		
	SD	1.00	1.00		0.73 (0.36-1.46)	0.71 (0.20-2.42)
	D	1.52 (0.69-3.37)	1.41 (0.69-3.37)			
	N	1.09 (0.46-2.58)	0.34 (0.07-1.50)			
	A	1.88 (0.85-4.20)	0.98 (0.22-4.43)			
	SA	1.27 (0.56-2.89)	1.68 (0.30-10.53)			
	Neighbourhood integrated within urban context			Local Choice (400m)		
	SD	1.00	1.00		1.00 (1.00-1.00)	**1.01(1.00-1.00)***
	D	1.63 (0.67-2.81)	1.58 (0.08-1.32)	Avg. Connectivity (400m)		
	N	0.92 (0.38-2.35)	**0.28 (0.06-1.17)***		0.47 (0.12-1.73)	0.17 (0.02-1.86)
	A	0.78 (0.37-2.20)	0.30 (0.06-1.65)			
	SA	0.93 (0.14-1.33)	0.21 (0.016.11)			
	Easy accessibility to bus-stops			Crow-fly distance to nearest bus-stop		
	SD	1.00	1.00		1.00 (1.00-1.01)	1.00 (1.00-1.00)
	D	1.20 (0.61-2.34)	2.94 (0.66-6.83)			
	N	1.10 (0.35-2.51)	1.11 (0.23-4.90)			
	A	1.61 (0.58-4.03)	**6.77 (0.86-150.69)***			
	SA	1.62 (0.57-6.78)	2.90 (0.30-73.19)			
	Presence of bus-stops			Segments with bus-stops		
	SD	1.00	1.00		0.68 (0.32-1.37)	1.24 (0.36-3.48)

	D	**0.54 (0.29-1.21)***	0.77 (0.21-3.00)			
	N	0.57 (0.23-1.41)	1.16 (0.27-6.89)			
	A	0.79 (0.36-2.33)	0.74 (0.23-5.66)			
	SA	2.13 (0.48-15.04)	5242548 (0.31-)			
Land-Use	Many stores within walking distance			Avg. non-residential land-use density		
	SD	1.00	1.00		1.00 (1.00-1.00)	1.01 (1.00-1.00)
	D	1.00 (0.51-1.95)	1.38 (0.40-4.69)			
	N	1.25 (0.43-3.83)	0.26 (0.05-1.50)			
	A	0.97 (0.41-2.33)	1.42 (0.29-10.59)			
	SA	0.79 (0.28-2.28)	0.56 (0.12-4.09)			
	Many destinations within walking distance			Avg. total land-use density		
	SD	1.00	1.00		1.00 (1.00-1.00)	**1.0 (1.00-1.00)***
	D	0.85 (0.44-1.63)	0.61 (0.19-1.88)			
	N	0.62 (0.25-1.56)	1.94 (0.36-13.66)			
	A	1.22 (0.47-3.31)	1.86 (0.27-37.72)			
	SA	1.53 (0.46-6.12)	3674343 (0.77-)			
Connectivity	Distance between street intersections short			Global Integration (400m)		
	SD	1.00	1.00		1.00 (1.00-1.00)	1.00 (1.00-1.00)
	D	1.28 (0.51-3.14)	0.28 (0.01-1.69)	Connectivity (400m)		
	N	1.65 (0.67-4.99)	0.30 (0.02-1.81)		0.53 (0.09-3.03)	0.23 (0.02-1.93)
	A	1.20 (0.45-3.15)	0.73 (0.03-8.39)			
	SA	1.40 (0.34-6.36)	0.20 (0.01-5.80)			
	Many alternate routes present between nodes			Local Choice (400m)		
	SD	1.00	1.00		1.15 (0.19-6.10)	**1.01 (1.00-**
	D	1.52 (0.85-2.74)	1.34 (0.39-4.88)			
	N	0.78 (0.39-1.57)	**0.34 (0.10-1.09)***			
	A	0.83 (0.38-1.84)	0.51 (0.13-2.10)			
	SA	1.35 (0.25-10.30)	0.30 (0.04-6.46)			
Aesthetics	Many unique buildings present along routes			Segments with landmarks		
	SD	1.00	1.00		0.98 (0.91-1.04)	1.01 (0.90-1.11)
	D	1.41 (0.57-3.94)	3.68 (0.67-22.72)			
	N	0.60 (0.26-1.56)	1.79 (0.39-7.95)			
	A	1.52 (0.67-4.18)	2.28 (0.72-11.52)			
	SA	0.95 (0.31-2.86)	**5.19 (0.73-49.45)***			
	Many landscape elements present along routes			Avg. density of recreational use		
	SD	1.00	1.00		1.00 (1.00-1.00)	1.00 (1.00-1.00)
	D	2.05 (0.49-9.32)	0.86 (0.07-4.13)			
	N	**3.71(0.91-16.58)***	0.72 (0.08-4.90)			
	A	**3.14 (0.80-13.50)***	2.01 (0.23-15.75)			
	SA	1.31 (0.33-5.55)	0.69 (0.07-4.81)			
	Sidewalks maintained			Streets with minimal problems (heaves, cracks, etc.)		
	SD	1.00	1.00		1.00 (0.99-1.01)	1.00 (0.98-1.03)
	D	1.21 (0.52-2.77)	1.28 (0.3-5.55)			
	N	**2.87 (1.09-7.67)***	1.64 (0.24-5.39)			
	A	1.53 (0.52-3.11)	1.35 (0.25-5.68)			
	SA	2.25 (0.79-6.51)	1.98 (0.28-17.72)			
	Presence of tree-aligned streets			Segments with trees		
	SD	1.00	1.00		1.00 (0.98-1.01)	1.00 (0.98-1.00)
	D	1.67 (0.73-3.71)	1.19 (0.23-4.11)			
	N	1.17 (0.48-2.72)	0.63 (0.12-2.05)			
	A	1.06 (0.37-2.21)	1.09 (0.15-3.50)			
	SA	**2.96 (0.91-8.55)****	2.36 (0.27-52.15)			
Safety	Crosswalks and traffic lights present			Segments with crosswalks/traffic lights		
	SD	1.00	1.00		1.00 (0.98-1.02)	0.97 (0.94-1.01)
	D	1.66 (0.67-3.54)	0.94 (0.13-4.71)			
	N	1.33 (0.52-2.87)	0.45 (0.06-1.74)			
	A	**2.18 (0.90-5.31)***	1.00 (0.13-5.85)			
	SA	**2.63 (1.00-7.04)****	0.92 (0.11-5.97)			

	Buffers present along sidewalks			Segments with buffers		
	SD	1.00	1.00		0.99 (0.96-1.03)	1.03 (0.97-1.07)
	D	1.28 (0.44-3.76)	1.23 (0.23-7.21)			
	N	1.28 (0.47-3.42)	1.21 (0.25-5.46)			
	A	1.74 (0.68-4.48)	2.22 (0.42-9.02)			
	SA	1.90 (0.60-4.53)	3.24 (0.49-17.89)			
	Parked cars on sidewalks			Segments with cars parked on sidewalk		
	SD	1.00	1.00		1.00 (0.99-1.02)	0.99 (0.97-1.01)
	D	**0.01(0.00-0.37)*** **	0.01 (0.00-4.33)			
	N	**0.01(0.00-0.32)*** **	0.01 (0.00-2.53)			
	A	**0.01(0.00-0.34)*** **	0.01 (0.00-5.24)			
	SA	**0.01(0.00-0.27)*** **	0.01 (0.00-2.20)			

*p≤0.10; **p≤0.05; ***p≤0.01; N=314
SD: Strongly Disagree; D: Disagree; N: Neutral; A: Agree; SA: Strongly Agree

aOR: adjusted Odds Ratio; CI: Confidence Interval
All measures are for 800 meter buffers, if not reported otherwise.
[c] Engaged in any versus no transportation walking
[d] Engaged in any transportation walking including walking to/from school versus other modes of commuting to school

5. Discussion

The results of this study demonstrate that environmental interventions within home-environment contribute to children's walking. Addressing components of road safety, accessibility and transportation environment appear to be central to increasing children's active commuting. For example, the prevalence of crossing aids and sidewalks may be promoted within school-areas to enhance perceived safety and accessibility, while perceived accessibility to bus-stops is a factor to consider in designing school-environments. Findings also demonstrate that continued effort to design mixed-use environments seem to facilitate walking. While more destinations within the immediate home-environment (400m-radius) increased the odds of meeting physical activity recommendations through recreational walking, higher home-environment land-use densities promoted the likelihood of transportation walking including walking to/from school.

Present results extend past studies by demonstrating significant associations with recreational and transportation walking using objective connectivity measures that can quantify the structural configuration of street networks. The correspondence between perceived distance between intersections and global Integration and between perceived integration of home-environment with its surroundings and global Integration and local Choice suggest that interventions into street network design might play a pivotal role in addressing perceptional barriers to children's physical activity. Increased street network connectivity with denser and hierarchical connections needs to be considered in the siting of new schools as well as in the regeneration of current school districts. Particularly for Istanbul, which is currently experiencing a massive urban regeneration process, this finding has potential for re-structuring the street network in both the older and newer areas. However, results also indicate that in addition to street-level improvements, increasing parental educational levels are also needed in changing travel behaviour.

Some of the limitations of this study are related to limited sample size and number of environmental attributes included. For example, the limited number of the audited segments within home-environments may account for the weak and non-significant relationships between audit-derived aesthetics variables and walking behaviour. This requires further attention in future research. Low associations between perceived safety attributes could be altered by including pedestrian counts per segment to account for the unmeasured safety from crime variable. Future work will address the expansion of the sample size and the inclusion of a wider range of variables. Nevertheless, this study is novel in its inclusion of parental perceptions, objective environmental factors, and the structural properties of the urban street network aimed at distinguishing between the differing correlates of recreational and transportation walking.

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