Neighborhood built environment typologies and adiposity in children and adolescents

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Neighborhood built environment typologies and adiposity in school age children.

Tracie A. BARNETT[1,2], PhD, Adrian E. GHENADENIK[1], PhD, Andraea VAN HULST[2,3], RN, PhD, Gisele CONTRERAS, MSc, Marie-Soleil Cloutier, PhD, Yan KESTENS[3,4], PhD, Basile CHAIX[6,7], PhD, Melanie HENDERSON[2,8], MD, PhD.

Affiliations: [1]Department of Family Medicine, McGill University, Montreal, QC, Canada; [2]Centre de recherche du CHU Sainte-Justine, Montreal, Canada; [3]École de santé publique de l'Université de Montréal, Montreal, Canada; [4]Centre de Recherche du Centre Hospitalier de l'Université de Montréal (CRCHUM), Montreal, Canada; [5]Centre Urbanisation Culture Société, [6]Inserm, Paris, France; [7]Université Pierre et Marie Curie-Paris6, UMR-S 707, Paris, France; [8]Department of Pediatrics, Université de Montréal, Montreal, Canada

Address correspondence to: Tracie A. Barnett, 5858, chemin de la Côte-des-Neiges, 3rd floor, Montreal, QC H3S 1Z1
Email: tracie.barnett@mcgill.ca
Phone: (514) 398-7375

Short title: Built environment and adiposity in youth

Abbreviations: BMI, body mass index; FMI, fat mass index; GIS, Geographic Information System; QUALITY, Quebec Adipose and Lifestyle Investigation in Youth; WC, waist circumference

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What's Known on This Subject: Specific neighborhood features (e.g., infrastructures that facilitate walking) have been associated with childhood obesity. Nonetheless, findings concerning their potential to influence energy-related behaviors and outcomes in youth are not consistently supported in the literature. To date, few studies have taken into account the interrelation between multiple neighborhood dimensions in relation to childhood and adolescent adiposity.

What This Study Adds: Participants living in neighborhoods with high volumes of vehicular traffic had greater adiposity, independent of other built environment features. Neighborhood walkability may be an important target for obesity prevention, and safety from vehicular traffic may need to be prioritized.

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Tracie A Barnett is the principal investigator of the QUALITY Residential study. She conceptualized and designed the study, carried out the statistical analyses, co-drafted the initial manuscript, and approved the final manuscript as submitted.

Adrian E Ghenadenik contributed to the statistical analyses, revised several versions of the manuscript, and approved the final manuscript as submitted

Gisele Contreras contributed to the statistical analysis and approved the final version of the manuscript.

Andraea Van Hulst coordinated and supervised neighborhood data collection, contributed to the analytic conceptualization, co-drafted the initial manuscript, and approved the final manuscript as submitted.

Marie-Soleil Cloutier helped develop and test the neighbourhood audit tools and reviewed and approved the final manuscript.

Yan Kestens contributed to data collection for the spatial component of the study, and approved the final manuscript as submitted.

Basile Chaix contributed to the analytic conceptualization, revised the manuscript, and approved the final manuscript as submitted.

Melanie Henderson is the principal investigator of the QUALITY study, contributed to data collection, reviewed and revised the manuscript, and approved the final manuscript as submitted.

ABSTRACT

Neighborhoods are complex multidimensional systems. However, the interrelation between multiple neighborhood dimensions is seldom considered in relation to youth adiposity. We created a neighborhood typology using a range of built environment features and examined its association with adiposity in youth.

Analyses are based on data from the QUALITY cohort, an ongoing study on the natural history of obesity in Quebec youth with a history of parental obesity. Adiposity was measured at baseline and follow up approximately 8 years later. Neighborhood features were measured at baseline through in-person neighborhood assessments and geocoded administrative data and were summarized using principal components analysis. Neighborhood types were identified using cluster analysis. Associations between neighborhood types and adiposity were examined using multivariable linear regressions.

Five distinct neighborhood types characterized by levels of walkability and traffic-related safety were identified. At ages 8-10 years, children in moderate walkability/low safety neighborhoods had higher adiposity than those residing in moderate walkability/high safety neighborhoods. Attenuated associations were detected between neighborhood types and adiposity 8 years later.

Neighborhoods characterized by lower traffic safety appear to be the most obesogenic to children, regardless of other walkability-related features. Policies targeting neighborhood walkability for children may need to prioritize vehicular traffic safety.

INTRODUCTION

Obesity is a complex multi-factorial condition with wide-ranging causes encompassing genetic, biological, behavioral and socio-environmental factors (1, 2). Youth obesity has tripled over the past generation and remains a dire public health challenge (3). Obesity in childhood persists into adulthood (4), and is linked to adult disease independently of later weight status (5). Upstream, socio-environmental approaches are essential in order to impact the population-level distribution of obesity, specifically by preventing or delaying the onset of overweight in childhood (6). Although our knowledge base for developing such interventions is still limited, (7, 8) significant area-level variation in the prevalence of obesity (9-13) suggests that specific types of neighborhoods may embody an 'obesogenic potential'. Neighborhood-level features are thought to influence obesity through energy-related behaviors (e.g.: diet, physical activity, sedentary behavior) (14-16). If salient environmental features implicated in pediatric obesity can be identified, reducing the obesogenic nature of neighborhoods through even minor environmental modifications could lead to significant population-level improvements.

Neighborhood features characterizing obesogenic environments likely differ between pediatric and adult populations (17, 18) (e.g., the detrimental effect of urban sprawl in adults (19) is inverted in adolescents (20)). These differences call for tailoring research and intervention to specific populations. Policy recommendations targeting schools and neighborhoods as key environments to support healthy lifestyle behaviors in youth largely reflect this strategy (21, 22). Nonetheless, despite the theoretical appeal of different neighborhood-level features in terms of their potential to influence energy-related behaviors, their association with these outcomes in youth is not consistently supported in the literature (14, 15, 23). Among different issues underlying inconclusive findings are heterogeneous conceptual and methodological approaches (24-26). These include the definition, operationalization and measurement of neighborhood features, predictors and outcome variables, and the analytic approaches and covariates included in statistical models (14, 23, 27). Furthermore, built environment features tend to be correlated with one another, therefore modeling their association with health outcomes requires consideration for their interrelated nature (28-30).

An approach suitable to this purpose is cluster analysis. Cluster-based statistical techniques categorizing neighborhoods in terms of attribute patterns (i.e.: neighborhood typologies) have been used in relation to physical activity in adults (31-33), adolescents (34, 35), and children (36), and also in relation to adiposity in adults (19, 37) and youth (38, 39). Aside from their contribution to identify areas representing different configurations of resources, these studies highlight the importance of accounting for the presence of both health-promoting and health-deterring features that contribute to shaping health area-level behaviour.

The aim of this study was to identify neighbourhood types based on objectively-assessed neighbourhood attributes, and cross-sectional and prospective associations with adiposity in children over time. The specific objectives were to: 1) create a neighborhood typology using a wide range of built environment features, including child-oriented features; 2) examine associations between neighborhood types and multiple measures of adiposity in children aged 8-10 years, and 3) examine if these types predict adiposity in these children approximately 8 years later, at ages 15-18 years.

PARTICIPANTS AND METHODS

Study design and participants

The analyses in this paper were based on data from the Quebec Adipose and Lifestyle InvesTigation in Youth (QUALITY) cohort, an ongoing longitudinal investigation of the natural history of obesity and cardiovascular risk factors in vulnerable children, and the complementary QUALITY Residential Study. This cohort comprises 630 children aged 8-10 years at baseline (2005-2008) and both biological parents. Families were recruited through elementary schools located within a 75-km radius of three major urban centers in the province of Quebec, Canada: Montreal, Quebec City and Sherbrooke. Eligibility criteria required participants to be Caucasian, aged 8–10 years at the time of recruitment, with both biological parents being available for the study and at least one of them being obese based on self-reported weight, height, and waist circumference (WC) (i.e., body mass index (BMI) of mother and/or father ≥30kg/m^2, or mother's WC ≥88 cm and/or father's WC ≥102 cm). Follow up was conducted approximately 8 years later (2012-2016) in 377 participants (retention rate=60%). A detailed description of the study design and data collection methods is available elsewhere (40). Analyses were restricted to participants for who full neighborhood environment data were available (n=485). Prospective analyses were restricted to participants with complete follow-up data (n=298). A diagram detailing the number of participants by time of survey and reasons for inclusion/exclusion from analytical samples is presented in Figure 1.

Measurements

Measurements in children

Adiposity measures were taken at both baseline and follow up. Weight was measured to the nearest 0.1kg using an electronic scale, with participants wearing lightweight indoor clothing without shoes or sweaters. Height was measured with a stadiometer, and was recorded to the nearest millimeter during maximal inspiration. Waist circumference (WC) was measured midway between the lowest rib and the superior border of the iliac crest with a non-stretchable fiberglass measurement tape. Anthropometric measurements were taken twice and averages were computed. If measurements differed by more than 0.2cm for height and WC, or 0.2kg for weight, a third measurement was taken, and the average between the two closest measurements was computed. BMI Z-scores were computed using CDC growth standards (41). Dual-energy X-ray absorptiometry was used to measure children's fat mass. Fat mass index (FMI) was computed by dividing total body fat mass by height in meters squared (kg/m^2) (42). The percentage of central body fat (computed as trunk fat mass/total fat mass x 100) was estimated using trunk fat mass obtained from the automatic region that consists of the chest, abdomen and pelvic area. Pubertal development stage was assessed by a nurse using the 5-stage Tanner scale (43, 44), and was dichotomized as pre-pubertal (Tanner 1) vs. puberty initiated (Tanner >1).

Measurements in parents

Both parents' weight and height were measured at baseline using the same instruments and protocol as in children. BMI was computed as weight (kg) divided by height squared (m^2).

Neighborhood environment features

Characteristics of the built and social environments in children's residential neighborhoods were obtained at baseline for families residing in the Montreal metropolitan area (n=512). Exact residential addresses of each participant were geocoded. Data were collected using two sources: 1) in-person neighborhood audits, and 2) administrative data.

Audits were performed using the QUALITY audit tool, an observation grid adapted from an existing neighbourhood assessment instrument (45). This grid includes a checklist scoring 60 street-level built environment features surrounding each participant's residential address. Audits were conducted by independent pairs of trained observers. Inter-rater reliability was substantial (kappa >0.60) (46) for most of the indicators used in our analyses. Built environment features of up to 10 street segments located within the immediate residential environment were subjected to a detailed assessment. Features recorded include: 1) the presence of sidewalks (absent, present on one side only, present on both sides); 2) the presence of pedestrian aids (zebra crossing, pedestrian crossing light, pedestrian crossing sign, all-direction stop sign at intersection, widened sidewalk at intersection, paved pedestrian crossing, designated 'school corridor'); 3) the presence of traffic calming measures (speed bump, mid-street segment stop sign, speed limit 30 km/h, traffic lights, large obstacles designed to decrease the number of driving lanes); and 4) signs of social disorder (graffiti, vandalism, litter, abandoned building/construction). Indicators were created reflecting the average number of sidewalks per street segment (ranging from 0 to 2), the proportion of street segments with at least one pedestrian aid, the proportion of street segments with at least one traffic calming measure, and having at least one street segment with one or more signs of social disorder, respectively.

Administrative data were collected using the MEGAPHONE database. This is a geographic information system (GIS) that seeks to characterize social, built and natural environmental factors to understand the relationship between contextual and compositional factors and health outcomes in the Montreal region (47). The following indicators were computed for 1km street-network buffers centered on the participants' residences: 1) the number of three-way -or more- intersections; 2) a measure of land use mix (residential, commercial, industrial, recreational, or other) based on an entropy equation resulting in a score of 0 to 1, where 0 represents homogeneity (all land uses within the area are of a single type), and 1 represents heterogeneity (even distribution of all land use categories within the area) (48); 3) number of parks; 4) percentage of streets within buffers that have heavy vehicular traffic at rush hour, categorized as less than 1%, 1-5%, and ≥5%; 5) total length of streets within the buffer that have normal vehicular traffic at rush hour; 6) total length of streets within the buffer that have heavy vehicular traffic at rush hour (categorized as 0 km, >0-1 km, >1-5 km, ≥5 km); 7) density of private dwellings per hectare (10000m^2); 8) a normalized difference vegetation index (NDVI) based on satellite images of the amount of chlorophyll present, the index ranges from -1 to 1, with greater values indicating more vegetation; and 9) the proportion of the buffer area covered by parks. In addition, as a measure of area-level socioeconomic status, the proportion of residents aged 24-64 years who completed a university degree, was computed using 2006 Census data for each buffer.

Statistical analysis

Identification of neighborhood types

A two-step approach was used to identify neighborhood types. First, principal component analysis (PCA) with varimax rotation was used to reduce neighborhood environment measures to a parsimonious number of distinct and meaningful components. A three-factor solution was selected based on the Kaiser criterion (Eigenvalues > 1), accounting for 62% of the total variance in the data. The first component (37% of variance) was defined by many intersections, more mixed land use, more parks, more sidewalks, more streets with low traffic and more signs of social disorder. The second component (14% of variance) was defined by meters of roadway and proportion of roadway with heavy traffic volume at rush hour, and the third component (11% of variance) was defined by the presence of traffic calming measures and pedestrian aids.

Following this step, and based on the three components from PCA, hierarchical cluster analysis using Ward's method (49) was used seeking to identify unique neighborhood types for subsequent examination in relation to child adiposity. This method starts with each multidimensional observation (neighborhood) as a single cluster and then repeatedly merges the next two closest clusters in terms of Euclidian distances between observations until a single, all-encompassing cluster remains (50). Application of this method results in a typology wherein neighborhoods that were substantively comparable on selected characteristics were grouped together despite not necessarily being geographically adjacent (51). A five-cluster solution was retained, with 68% of the variation in the data explained by the variables included in the clusters.

Neighborhood typology and adiposity
Dummy variables were created for each cluster, and multiple linear regression was used to examine associations between neighborhood types and adiposity indicators at baseline and follow-up. Models were adjusted for age, sex, pubertal development, percentage of university-educated residents, and parental BMI scores. Prospective analyses were restricted to participants who remained at the same address between baseline and follow up (n=226). Prospective models were adjusted using the same covariates as cross-sectional models, except for pubertal development, as all participants had initiated puberty at follow-up. Sensitivity analyses using different neighborhood types as referent were conducted to test the robustness of results obtained from the main models. Analyses were conducted using SAS v9.2 and Stata v15.

RESULTS
Descriptive statistics for the five neighborhood types are presented in Table 1. Patterns emerged based on two dimensions, *walkability* and *safety*. *Walkability* was characterized by number of intersections, dwelling density, total street length, sidewalks, pedestrian aids, and parks; *safety* was based on indicators of rush hour vehicular traffic and of traffic calming measures. Type 1 neighborhoods (n=132) were defined as '*moderate walkability and high safety'*; type 2 neighborhoods (n=115) as '*low walkability and high safety'*; type 3 neighborhoods (n=64) as '*moderate walkability and moderate safety*'; type 4 neighborhoods (n=108) as '*high walkability and moderate safety'*; and type 5 neighborhoods (n=66) as '*moderate walkability and low safety'*.

Characteristics of participants by neighborhood type are presented in Table 2. Mean age of children, maternal BMI, and pubertal status were similar across neighborhood types. Differences by neighborhood type were observed in terms of paternal BMI and all indicators of child adiposity, chiefly in Type 5 neighborhoods, where participants were more likely to have higher adiposity compared to those residing in other neighborhoods. Also, differences were found in terms of child's sex, with lower proportions of boys in Type 3 neighborhoods and lower proportions of girls in Type 4 neighborhoods.

Fully-adjusted cross-sectional associations between neighborhood types and adiposity indicators are presented in Table 3. Results show that children residing in Type 5 neighborhoods (*moderate walkability and low safety*) had higher BMI Z-scores [β: 0.41 (0.11; 0.71)], FMI [β: 1.22 (0.28; 2.16)], waist circumference [β: 4.90 (1.60; 8.21)], and central fat mass percentage [β: 1.60 (0.03; 3.17)] compared to their Type 1 neighborhood counterparts (reference category). Sensitivity analyses using other neighborhood types as referents, chiefly those with relatively high safety showed similar results, highlighting the importance of this dimension in terms of its association with adiposity indicators (see Supplementary Materials for details).

Fully-adjusted prospective associations between neighborhood types and adiposity indicators are presented in Table 4, and generally extend cross-sectional findings. Although no statistically significant results between neighborhood types and adiposity indicators were detected, attenuated associations (p value <0.10) between Type 5 neighborhoods and a larger waist circumference FMI [β: 1.42 (-0.06; 2.91)], and waist circumference [β: 5.06 (-0.24; 10.36)] were observed in adolescents. Sensitivity analyses using other neighborhood types as referents showed similar results, supporting the robustness of these findings.

DISCUSSION

This study used a novel approach seeking to identify patterns of neighborhood-level environmental features (as opposed to examining individual attributes in isolation), and their association with child and youth adiposity. We used a wide range of both direct observation and GIS-derived measures of residential neighborhood characteristics to generate distinct neighborhood types. Walkability and safety emerged as the salient constructs characterizing distinct types of neighborhoods containing complex combinations of both positive and negative environmental influences. In our sample, we identified five types in the best fitting model, which we labeled as: 1) moderate walkability/high safety, 2) low walkability/high safety, 3) moderate walkability/moderate safety, 4) high walkability/moderate safety, and 5) moderate walkability/ low safety.

Cross-sectional analyses, which examined associations between neighborhood types and adiposity indicators in children aged 8-10 years, showed that participants living in neighborhoods characterized by moderate walkability, and most importantly, low safety levels, had higher adiposity (BMI z-scores, FMI, waist circumference and central fat mass percentage) than their counterparts residing in other neighborhood types. These findings suggest that safety may play an important role in shaping adiposity outcomes in this age group. Studies including a recent systematic review of traffic-related environmental factors and childhood obesity have indeed reported associations between of objective and subjective measures of vehicular traffic-related safety and adiposity/obesity indicators (52). Low levels of traffic-related safety may discourage active transportation and outdoor play even in areas with moderate or high walkability -such as Type 5 neighborhoods in this study, which were moderately walkable but less safe-. In these areas, destinations including schools, shops and play areas may be within walking distance, however high volumes of local traffic may discourage active transportation, and time spent outdoors (53-57). In such neighborhoods, children may not have parental permission -or may not choose- to venture into these destinations (58). In this vein, several reviews have underscored pedestrian safety structures as one of the features most consistently associated with PA in children (14, 59, 60), and studies have reported associations between presence of pedestrian infrastructures such as sidewalks and access to paths and higher levels of physical activity (61, 62) and lower body weight (63, 64).

Prospective models detected attenuated associations between neighborhood types and adiposity in participants 8 years later (ages 15-17). Despite their lack of statistical significance, which may be partly due to lack of sufficient statistical power, these results are in line with those from cross-sectional models, and provide some support for the potential role of low-safety neighborhoods in influencing adiposity in adolescence. Very few studies have examined associations between road safety and obesity/adiposity in adolescents: most have focused their efforts on putative mediators such as physical activity (PA) and/or active transportation. In any case, the evidence concerning obesity and adiposity outcomes (52, 65), as well as PA (66, 67) in this age group remains inconclusive.

Whereas associations in adolescents are directionally similar to those detected 8 years earlier, their attenuated nature may be indicative of a less prominent role of traffic safety features as promoters or deterrents of energy expenditure in adolescents. The authors of one the above-cited reviews (66) propose that this is because teenagers typically have less parental constraints regarding traffic safety issues, and therefore they use their immediate neighborhood features differently than children. Also, these results may point to a more limited relevance of the immediate residential environment to adolescents, as their activity spaces likely go beyond their area of residence. Therefore, our exclusive focus on surrounding residential areas may not be reflective of the full range of environmental exposures to which adolescents may be exposed to. Future studies should strive to incorporate other activity spaces to test whether non-residential areas are associated with adiposity outcomes in this age group

This study has several strengths. First, the environmental assessments using both territorial and ego-centric neighborhood definitions allowed us to capture a wide array of features to which children and adolescents are exposed to. Second, the analyses in this paper go beyond BMI as the sole measure of adiposity, to also include direct measures including waist circumference, fat mass index, and percentage of central fat mass. Of note, most studies have relied on BMI rather than on direct measures of body fat (68, 69) due to the relative ease in collecting information on weight and height. Although useful for surveillance and individual assessment purposes, BMI tends to be a more reliable measure of excess weight for height than of excess adiposity (70). Third, our findings cover an important stage of the life course, spanning from childhood to adolescence. Fourth, our methodology allowed for the examination of an array of environmental features whose effects may be difficult to disentangle using multivariable regression analyses due to multicollinearity (28). Moreover, cluster analysis methods allow to take into account the multidimensional nature of neighborhoods by which a combination of features, rather than individual ones, may influence health outcomes and behaviors (71-73). Looking at neighborhoods as combinations of multiple factors, may provide a more complete picture of the interaction of the environment with health.

Some limitations must be noted as well. First, the study sample was limited to Caucasian children at risk of obesity. Furthermore, participants in this cohort are relatively more socially advantaged than the average in the province of Quebec. These two issues potentially limit the generalizability of our findings. Second, differential loss to follow-up of families living in more disadvantaged areas, who tend to have worse adiposity outcomes, may have resulted in some selection bias. Third, and despite being a key component to this study's typology, neighborhood walkability did not emerge as a strong correlate of obesity. Although the measures used in this study incorporated several child-specific measures such as parks and 'school corridors', it is possible that the inclusion of a more focused set of indicators (e.g.: specific park features, recreational resources, and school proximity) would generate a more child-centric construct of walkability. Future research should seek to further establish more nuanced constructs of walkability relevant to children, taking into consideration their development stage and their level of independent mobility. Fourth, since the neighborhood features included in the typology were only measured at baseline, it is possible that some of these have changed over the course of the 8 years after their assessment. This may have resulted in some misclassification bias, and may partly explain the lack of significant associations between traffic safety and adiposity in adolescents. Finally, as mentioned above, this paper focused exclusively on proximal residential environments. This is likely of limited concern in younger children, as the residential neighborhood typically constitutes the most important activity space in this age group (74). Future studies should also capture activity spaces beyond the residential environment in order to capture spatial and temporal variation in exposure to contextual features (75-77).

CONCLUSION

Our study is one of the first studies to identify neighbourhood typologies and cross-sectional and prospective associations with adiposity in youth. Findings constitute an original contribution to the research literature by simultaneously examining the influence of multiple indicators of neighborhood characteristics on various measures of adiposity, at childhood and adolescence. Findings highlighting associations between areas characterized by relatively low traffic safety and a higher risk of adiposity in children suggest this may be a promising target for public health intervention. The examination of neighbourhood typologies may be a promising avenue for informing urban design through understanding how different combinations of neighbourhood environments influence health, and may provide guidance for policy and urban planners. Future research should also examine potential mechanisms of typology-health associations.

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Table 1. Description of area features by neighborhood type in the QUALITY cohort 2005-2008

	Type 1: *MODERATE WALKABILITY AND HIGH SAFETY* (n=132)	Type 2: *LOW WALKABILITY AND HIGH SAFETY* (n=115)	Type 3: *MODERATE WALKABILITY AND MODERATE SAFETY* (n=64)	Type 4: *HIGH WALKABILITY AND MODERATE SAFETY* (n=108)	Type 5: *MODERATE WALKABILITY AND LOW SAFETY* (n=66)
WALKABILITY					
Number of intersections, mean (SD)	70.77 (31.08)	60.58 (25.60)	70.94 (30.05)	119.76 (30.25)	80.50 (42.62)
Land use mix, mean (SD)	0.32 (0.12)	0.30 (0.13)	0.29 (0.13)	0.55 (0.10)	0.32 (0.12)
Density of private dwellings per hectare, % (n)	2.71	2.75	3.45	4.85	2.98
High density	2.27 (3)	2.61 (3)	17.19 (11)	87.96 (95)	13.64 (9)
Average-to-high density	24.24 (32)	25.22 (29)	40.63 (26)	10.19 (11)	21.21 (14)
Average density	31.06 (41)	30.43 (35)	20.31 (13)	0.93 (1)	25.76 (17)
Average-to-low density	27.27 (36)	28.70 (33)	14.06 (9)	0.93 (1)	28.79 (19)
Low density	15.15 (20)	13.04 (15)	7.81 (5)	0	10.61 (7)
Total length of streets with normal vehicular traffic at rush hour, km, mean (SD)	204.91 (89.49)	209.03 (92.48)	317.52 (140.73)	570.24 (188.84)	225.32 (128.70)
Presence of sidewalks, % (n)	2.03	2.16	2.59	4.72	2.29
All segments with sidewalks on both sides	0.76 (1)	0	12.50 (8)	77.78 (84)	10.61 (7)
High presence of sidewalks	17.42 (23)	13.04 (15)	17.19 (11)	19.44 (21)	16.67 (11)
Moderate presence of sidewalks	18.18 (24)	33.04 (38)	23.44 (15)	0.93 (1)	13.64 (9)
Low presence of sidewalks	11.36 (15)	10.43 (12)	10.94 (7)	0.93 (1)	9.09 (6)
No segments with sidewalks	52.27 (69)	43.48 (50)	35.94 (23)	0.93 (1)	50.00 (33)
Proportion of segments with ≥ 1 pedestrians aid, mean (SD)	43.80 (28.58)	71.54 (20.57)	64.47 (24.94)	53.18 (26.72)	46.36 (28.18)
Number of parks, mean (SD)	2.11 (1.29)	0.80 (0.77)	1.41 (1.26)	3.68 (1.30)	2.80 (1.50)
Park area ratio, % (n)	1.95	1.25	1.51	2.59	2.15
< 0.01	22.73 (30)	75.65 (87)	51.56 (33)	1.85 (2)	10.61 (7)
0.1 to < 0.05	59.85 (79)	23.48 (27)	45.31 (29)	37.04 (40)	63.64 (42)
≥ 0.05	17.42 (23)	0.87 (1)	3.13 (2)	61.11 (66)	25.76 (17)

VEHICULAR TRAFFIC-RELATED SAFETY					
Neighborhood streets with heavy vehicular traffic at rush hour, % (n)					
< 1%	100 (132)	100 (115)	0	100 (108)	0
1 to 5%	0	0	93.75 (60)	0	48.48 (32)
≥ 5%	0	0	6.25 (4)	0	51.52 (34)
Total length of streets with heavy vehicular traffic at rush hour, % (n)	0.52	0.53	2.80	1.47	2.79
0 km	52.27 (69)	54.78 (63)	0	0.93 (1)	0
0.1 to 1 km	43.18 (57)	37.39 (43)	0	50.93 (55)	0
1.1 to 5 km	4.44 (6)	7.83 (9)	20.31 (13)	48.15 (52)	21.21 (14)
≥ 5 km	0	0	79.69 (51)	0	78.79 (52)
Proportion of streets with ≥ 1 traffic calming measure, mean (SD)	13.94 (17.30)	33.36 (24.93)	29.38 (27.53)	40.47 (25.87)	9.85 (16.11)
OTHER					
NDVI, mean (SD)	0.37 (0.07)	0.33 (0.06)	0.32 (0.06)	0.24 (0.06)	0.37 (0.05)
Presence of signs of social disorder, % (n)	18.18 (24)	23.48 (27)	39.06 (25)	75.93 (82)	15.15 (10)
Neighborhood residents with university education, %, mean (SD)*	26.89 (14.61)	25.98 (13.038)	27.20 (11.35)	33.52 (13.16)	28.13 (16.24)

* Variables not used in cluster analysis to define neighborhood types
NDVI, Normalized difference vegetation index

Table 2. Baseline characteristics of 485 children from the QUALITY cohort, by neighborhood type, 2005-2008

	Type 1: *MODERATE WALKABILITY AND HIGH SAFETY* (n=132)	Type 2: *LOW WALKABILITY AND HIGH SAFE* (n=115)	Type 3: *MODERATE WALKABILITY AND MODERATE SAFETY* (n=64)	Type 4: *HIGH WALKABILITY AND MODERATE SAFETY* (n=108)	Type5: *MODERATE WALKABILITY AND LOW SAFETY* (n=66)
Age, years, mean (SD)	9.58 (0.94)	9.55 (0.93)	9.68 (0.90)	9.55 (0.89)	9.83 (0.84)
Boys, % (n)	53.79 (71)	53.04 (61)	37.50 (24)	63.89 (69)	56.06 (37)
Puberty initiated, % (n)	20.61 (27)	23.48 (27)	23.44 (15)	23.15 (25)	30.30 (20)
Child's BMI Z-score, mean (SD)	0.58 (1.05)	0.66 (1.04)	0.65 (1.14)	0.72 (1.10)	1.10 (0.93)
FMI, kg/m^2, mean (SD)	5.03 (2.93)	5.30 (3.38)	5.74 (3.38)	5.59 (3.75)	6.73 (3.83)
WC, cm, mean (SD)	65.77 (10.09)	66.52 (11.85)	67.75 (12.26)	68.25 (13.24)	72.76 (14.30)
% central fat mass, mean (SD)	40.44 (4.71)	39.85 (5.48)	41.85 (6.12)	40.55 (5.76)	42.72 (5.09)
Mother's BMI, kg/m^2, mean (SD)	29.25 (6.35)	29.77 (6.61)	29.76 (7.30)	29.77 (6.03)	29.52 (7.52)
Father's BMI, kg/m^2, mean (SD)	30.59 (5.27)	30.75 (5.072)	30.54 (6.46)	29.89 (5.36)	32.84 (6.43)

BMI, body mass index; FMI, fat mass index; SD, standard deviation; WC, waist circumference

Table 3. Results of fully-adjusted linear regression models predicting adiposity at baseline among 485 children aged 8-10 years from the QUALITY cohort, using neighborhood types as predictors, 2005-2008

	Overall Adiposity				**Central Adiposity**			
	BMI Z-Score		**FMI (kg/m²)**		**Waist Circumference (cm)**		**% Central Fat Mass**	
	β (95% CI)				β (95% CI)			
Intercept	1.53	0.45, 2.62	-6.58	-10.51, 2.65	13.49	-0.43, 27.40	26.47	19.90, 33.04
Neighborhood type								
Type 1: *MODERATE WALKABILITY, HIGH SAFETY*		Referent		Referent		Referent		Referent
Type 2: *LOW WALKABILITY, HIGH SAFETY*	0.05	-0.20, 0.30	0.17	-0.61, 0.94	0.42	-2.32, 3.17	-0.68	-1.97, 0.62
Type 3: *MODERATE WALKABILITY, MODERATE SAFETY*	0.10	-0.19, 0.40	0.51	-0.43, 1.44	1.86	-1.43, 5.14	1.05	-0.52, 2.61
Type 4: *HIGH WALKABILITY, MODERATE SAFETY*	0.14	-0.12, 0.40	0.67	-0.14, 1.48	2.44	-0.42, 5.30*	0.41	-0.94, 1.76
Type 5: *MODERATE WALKABILITY, LOW SAFETY*	0.41	0.11, 0.71***	1.22	0.28, 2.16**	4.90	1.60, 8.21***	1.60	0.03, 3.17**
Child's age	-0.10	-0.21, 0.01	0.43	0.09, 0.77**	2.61	1.41, 3.82***	0.58	0.01, 1.14**
Sex (boys)	0.20	-0.001, 0.40	-0.63	-1.26, -0.01**	1.64	-0.56, 3.84	-1.45	-2.49, -0.40***
Puberty initiated	0.42	0.16, 0.67***	1.33	0.54, 2.12***	5.37	2.56, 8.17***	0.93	-0.39, 2.25
University-educated residents, %	-0.01	-0.08, 0.06	-0.01	-0.03, 0.01	-0.02	-0.10, 0.05	-0.01	-0.04, 0.03
Mother's BMI, kg/m²	0.04	0.03, 0.05***	0.12	0.08, 0.16***	0.39	0.23, 0.54***	0.17	0.10, 0.25***
Father's BMI, kg/m²	0.05	0.03, 0.06***	0.13	0.08, 0.18***	0.47	0.29, 0.64***	0.13	0.05; 0.22***

* <0.10 ** <0.05 *** <0.01

Abbreviations: BMI, body mass index; FMI, fat mass index

Table 4. Results of fully-adjusted linear regression models predicting adiposity among 298 participants aged 15-17 from the QUALITY cohort who resided at the same address both at baseline and follow-up, using neighborhood types as predictors, 2005–2016

	Overall Adiposity				Central Adiposity			
	BMI Z-Score		FMI (kg/m^2)		Waist Circumference (cm)		% Central Fat Mass	
	β (95% CI)				β (95% CI)			
Intercept	-0.64	-3.03, 1.75	-0.11	-9.05, 8.82	38.46	7.00, 69.92	26.01	13.73, 38.29
Neighborhood type								
Type 1: *MODERATE WALKABILITY, HIGH SAFETY*		Referent		Referent		Referent		Referent
Type 2: *LOW WALKABILITY, HIGH SAFETY*	-0.10	-0.43, 0.23	-0.08	-1.29, 1.13	0.09	-4.22, 4.40	-0.63	-2.29, 1.03
Type 3: *MODERATE WALKABILITY, MODERATE SAFETY*	-0.28	-0.66, 0.09	-0.71	-2.10, 0.68	-1.41	-6.36, 3.54	-1.60	-3.51, 0.31*
Type 4: *HIGH WALKABILITY, MODERATE SAFETY*	0.02	-0.33, 0.38	-0.01	-1.32, 1.31	0.47	-4.20, 5.14	-0.45	-2.26, 1.36
Type 5: *MODERATE WALKABILITY, LOW SAFETY*	0.25	-0.15, 0.65	1.42	-0.06, 2.90*	5.06	-0.24, 10.36*	0.12	-1.92, 2.16
Child's age	-0.06	-0.19, 0.07	0.11	-0.36, 0.59	0.99	-0.69, 2.67	1.04	0.39, 1.69***
Sex (boys)	0.07	-0.18, 0.31	-2.59	-3.49, -1.70***	6.54	3.35, 9.73***	2.16	0.92, 3.39***
University-educated residents, %	-0.03	-0.12, 0.06	-0.18	-0.51, 0.14	-0.22	-1.37, 0.93	-0.19	-0.64, 0.25
Mother's BMI, kg/m^2	0.05	0.03, 0.07***	0.13	0.06, 0.21***	0.38	0.11, 0.65***	0.06	-0.04, 0.16
Father's BMI, kg/m^2	0.03	0.01, 0.05**	0.10	0.01, 0.19**	0.34	0.02 0.67**	0.06	-0.07; 0.19

* <0.10 ** <0.05 *** <0.01

Abbreviations: BMI, body mass index; FMI, fat mass index

Figure 1. Diagram detailing the number of participants by time of survey and reasons for inclusion/exclusion from analytical samples