Associations Between Children's Diets and Features of Their Residential and School Neighbourhood Food Environments

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ABSTRACT

Objectives: Among studies of the built environment, few examine neighbourhood food environments in relation to children's diets. We examined the associations of residential and school neighbourhood access to different types of food establishments with children's diets.

Methods: Data from QUALITY (Quebec Adipose and Lifestyle Investigation in Youth), an ongoing study on the natural history of obesity in 630 Quebec youth aged 8-10 years with a parental history of obesity, were analyzed (n=512). Three 24-hour diet recalls were used to assess dietary intake of vegetables and fruit, and sugar-sweetened beverages. Questionnaires were used to determine the frequency of eating/snacking out and consumption of delivered/take-out foods. We characterized residential and school neighbourhood food environments by means of a Geographic Information System. Variables included distance to the nearest supermarket, fast-food restaurant and convenience store, and densities of each food establishment type computed for 1 km network buffers around each child's residence and school. Retail Food Environment indices were also computed. Multivariable logistic regressions (residential access) and generalized estimating equations (school access) were used for analysis.

Results: Residential and school neighbourhood access to supermarkets was not associated with children's diets. Residing in neighbourhoods with lower access to fast-food restaurants and convenience stores was associated with a lower likelihood of eating and snacking out. Children attending schools in neighbourhoods with a higher number of unhealthful relative to healthful food establishments scored most poorly on dietary outcomes.

Conclusions: Further investigations are needed to inform policies aimed at shaping neighbourhood-level food purchasing opportunities, particularly for access to fast-food restaurants and convenience stores.

Key words: Built environment; children; diet; food environment; residential neighbourhood; school neighbourhood; QUALITY cohort

La traduction du résumé se trouve à la fin de l'article.

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In recent years, the role of neighbourhoods has been increasingly investigated with respect to obesity in children.[1-3] Neighbourhood built environments may promote childhood obesity by favouring antecedent behaviours, including physical inactivity and unhealthful diets. Compared with physical activity, fewer studies have addressed children's diets.[1]

Most studies examining associations between local neighbourhood availability of food establishments and residents' diets have focused on adults.[4] Overall, findings from studies involving children are less consistent, notably for associations between access to supermarkets and vegetable and fruit (V&F) intake.[5-7] Greater access to convenience stores, which typically offer limited fresh produce, has been found to be associated with lower V&F intake[5,7] and higher intake of sweet/salty snacks[6] and sugar-sweetened beverages[8] in youth. Although some studies have reported associations between the availability of fast-food restaurants near children's residence and their diets,[7,8] others do not support such findings.[6,9,10] Given the conflicting results in the literature, there is a need to clarify the relation between neighbourhood food environments and children's diets.

In addition to residential neighbourhoods, school neighbourhood environments are relevant activity spaces and should be investigated in relation to obesity-related behaviours in children.[11,12] During the academic year, travel to and from school exposes children to school neighbourhood food environments. Recently, policies have targeted in-school food environments, but initiatives aimed at regulating food opportunities in school neighbourhoods have yet to be widely implemented. Fast-food restaurants and convenience stores are known to cluster within short distances from schools.[13,14] However, it is not clear to what extent the availability of the latter is associated with children's diet.[2,9]

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Conflict of Interest: None to declare.

The aim of this study was to determine whether features of residential and school neighbourhood food environments were associated with children's dietary intake (V&F and sugar-sweetened beverages) and selected dietary behaviours (eating/snacking out and consuming delivered/take-out food).

METHODS

Participants were drawn from the QUALITY (Quebec Adipose and Lifestyle Investigation in Youth) study, an ongoing longitudinal investigation of the natural history of obesity and cardiovascular risk in youth with a history of parental obesity. Recruitment flyers were distributed to parents of children in Grades 2 to 5 in 1,040 primary schools (89% of schools approached) located within 75 km of each of Montreal, Quebec City and Sherbrooke, QC. Of 3,350 interested families who contacted the research coordinator, 1,320 met the study inclusion criteria. Eligibility criteria required participating children to be Caucasian, aged 8-10 years at recruitment and to have at least one obese biological parent (i.e., body mass index [BMI] ≥30 kg/m^2 and/or waist circumference >102 cm in men and >88 cm in women, based on self-reported measurements of height, weight and waist circumference) and both biological parents available to participate at baseline. Of eligible families, a total of 630 (48% of eligible families composed of the participating child and two biological parents) completed the baseline visit between September 2005 and December 2008. Baseline data collection involved a clinic visit during which questionnaires were completed and biological and physiological measurements obtained, as well as follow-up telephone interviews. Written informed consent was obtained from parents, and assent was provided by children. The ethics review boards of Centre Hospitalier Universitaire Sainte-Justine and Laval University approved the study. A detailed description of the study design and methods is available elsewhere.[15]

Characteristics of the built and social environments in children's residential neighbourhood were obtained for the study baseline using a Geographic Information System (GIS) for 512 children residing in the Montreal Census Metropolitan Area (CMA). Of these, 506 attended some 296 schools located within the Montreal CMA, for which school neighbourhood GIS data were also obtained.

Dietary assessment

Children's dietary intake was measured using mean values of three 24-hour diet recalls conducted by trained dieticians on non-consecutive days, including one weekend day.[16] Data from recalls were available for 498 participants considered in this study. Except in unusual circumstances, the recalls were collected within a 4-week period after the baseline clinic visit. Diet recall interviews were done by telephone with the child and then confirmed with the parent who prepared the meals.

Foods reported on the recalls were entered into CANDAT (London, ON) and converted to nutrients using the 2007b Canadian Nutrient File.[17] Daily servings of V&F were based on portion sizes from Canada's Food Guide and include V&F juices. A dichotomous variable was developed on the basis of recommended servings of V&F for children aged 8-10 years: ≥5 servings/day vs. less.[18] Intake of sugar-sweetened beverages was computed as the mean daily number of millilitres of soft drinks and other sugar-sweetened drinks, but excluding juices made from real fruits. Given a substantial positive skewness in its distribution, sugar-sweetened beverage intake was dichotomized to >50 mL/day (approximately one can of soft drink per week) vs. less.

Two additional measures of children's diets were obtained from a questionnaire administered to the child during the clinic visit: having a meal or snack in a food establishment at least once in the previous week and consuming delivered or "take-out" food at least once in the previous week.

Neighbourhood assessment

The exact addresses of each participating child's residence and school were geocoded. The availability of food establishments within the residential and school neighbourhood environment was measured using a GIS, which included data from an exhaustive list, acquired from Tamec Inc., of businesses and services located in the region in May 2005. The business name, address, postal code and Standard Industry Classification code were available. A validity study of food establishments from this list, verified by onsite field visits, showed good agreement (0.77), sensitivity (0.84) and positive predictive value (0.90).[19] All businesses were geocoded using GeoPinPoint™, version 2007.3 (DMTI Spatial Inc.). Types of food establishment included in this study were supermarkets, fast-food restaurants,[14] convenience stores and specialty food stores (e.g., bakeries, fruit and vegetables, gourmet, meat and fish markets).

Neighbourhood food environments were described by proximity- and density-based indicators. Proximity measures were established using ArcGIS Network Analyst (Esri, Redlands, CA) and defined as the road-network distance between the child's residence and the nearest supermarket, fast-food restaurant and convenience store, and between the child's school and the nearest of each food establishment type. Because of highly skewed distributions, indicators were categorized into tertiles corresponding to farthest, intermediate and shortest distances. Kernel density was used to estimate the average density of each type of food establishment within 1 km street network buffers centred on 1) the child's residence and 2) the child's school. Kernel density estimations are frequently used in geography to evaluate the local density of point-based data[20] and have been used previously to describe neighbourhood access to food establishments.[21] A quartic kernel function was used with adaptive bandwidth composed of 1% of the observations for each type of food establishment (n=1,929 for convenience stores, n=1,118 for fast-food restaurants and n=828 for supermarkets) and cell spacing of 100 m. Exposure categories for each type of food establishment were based on tertiles corresponding to lowest, intermediate and highest densities.

Additionally, a Retail Food Environment Index (RFEI) was computed.[22] This index is based on the ratio of the number of fast-food restaurants and convenience stores to supermarkets and specialty food stores. Higher scores are indicative of neighbourhoods characterized by a higher number of unhealthful relative to healthful options. The RFEI was computed for 1 km network buffers and for 3 km radius circular buffers centred on each of the residential and school locations. A larger buffer was examined to capture greater variation among neighbourhoods in RFE indices. The index was subsequently categorized according to the approximate 75th percentile of each variable's distribution, corresponding to cut-offs of ≥2.0 vs. less for 1 km buffers and ≥2.5 vs. less for 3 km buffers.

Table 1. Characteristics of Participants Residing Within the Montreal CMA (n=512) From the Quebec Adipose and Lifestyle Investigation in Youth (QUALITY) Study

Characteristic	
Mean (SD) age, years	9.6 (0.9)
% (n) of male sex	54.5 (279)
Mean (SD) annual household income, $*	43,063 (18,722)
Highest level of education of either parent, % (n)	
2 parents with secondary school or less	8.3 (42)
1 or 2 parents with technical/vocational/trade degree	38.5 (196)
1 or 2 parents with university degree	53.2 (271)
Mean (SD) BMI of mothers, kg/m^2	29.5 (6.6)
Mean (SD) BMI of fathers, kg/m^2	30.8 (5.6)
Mean (SD) no. of daily servings of V&F	4.3 (2.1)
≥5 servings of V&F per day, % (n)	33.7 (168)
>50 mL of sugar-sweetened beverages per day, % (n)	58.0 (289)
Eat/snack out at least once per week, % (n)	43.8 (224)
Delivered/take-out food at least once per week, % (n)	35.0 (179)
Residential neighbourhood	
Median (IQR) population density per km^2	2715 (1926-3815)
% aged ≥15 years with no high school diploma, mean (SD)	32.6 (9.0)
% aged ≥15 years who are employed, mean (SD)	67.0 (8.3)
Mean (SD) total income of households, $	85,793 (23,197)
Median (IQR) walking distance from residence to school, metres	1121 (631-2535)
Proximity measures (distance to nearest), metres	
Supermarket, median (IQR)	1375 (739-2434)
Fast-food restaurant, median (IQR)	1326 (784-2256)
Convenience store, median (IQR)	779 (425-1327)
Kernel density measures (for 1 km network buffer), no./km^2	
Supermarket, median (IQR)	0.08 (0.03-0.2)
Fast-food restaurant, median (IQR)	0.2 (0.08-0.8)
Convenience store, median (IQR)	0.3 (0.1-1.0)
Retail Food Environment Index	
1 km network buffer, median (IQR)	1.0 (0-2.0)
3 km circular buffer, median (IQR)	1.8 (1.2-2.5)
School neighbourhood†	
Median (IQR) population density per km^2	2990 (2093-4087)
% aged ≥15 years with no high school diploma, mean (SD)	32.9 (9.1)
% aged ≥15 years who are employed, mean (SD)	64.0 (8.1)
Mean (SD) total income of households, $	81,478 (20,793)
Proximity measures (distance to nearest), metres	
Supermarket, median (IQR)	1008 (540-1999)
Fast-food restaurant, median (IQR)	950 (572-1889)
Convenience store, median (IQR)	541 (311-931)
Kernel density measures (for 1 km network buffer), no./km^2	
Supermarket, median (IQR)	0.1 (0.03-0.3)
Fast-food restaurant median (IQR)	0.3 (0.1-1.0)
Convenience store median (IQR)	0.5 (0.2-1.6)
Retail Food Environment Index	
1 km network buffer, median (IQR)	0.8 (0-1.8)
3 km circular buffer, median (IQR)	1.7 (1.2-2.4)

* Adjusted for the number of people living in the household.
† School neighbourhood data available for 296 schools localized within the Montreal CMA attended by 506 QUALITY study children (6 attended a school outside the study area).
CMA=Census Metropolitan Area; BMI=body mass index; V&F=vegetables and fruit; IQR=inter-quartile range.

Other neighbourhood-level measures included a material deprivation index computed from 2006 Census data.[23] The index combines the proportion of people with no high school diploma, the proportion who are employed and the average income, for people aged ≥15 years in census dissemination areas. Population-weighted proportions of dissemination areas overlapping 1 km street network buffers centred on resident's location were computed. The index was classified into quintiles of lowest to highest deprivation. A material deprivation index for school neighbourhood was computed using the same approach. Population density for both residential and school neighbourhood environments was computed from 2006 Census data for 1 km street network buffers. A median split categorization was used for measures of population density.

Individual socio-demographic measures

Individual-level data used as adjustment variables included child's age and sex, and mother's BMI. Highest parental educational attainment (2 parents with secondary school or less, ≥1 parent with technical/vocational/trade degree, ≥1 parent with university degree) and total annual household income adjusted for the number of people living in the household were obtained from parent-completed questionnaires during the clinic visit.

Analysis

This study was not designed to allow multilevel analyses of participants nested into neighbourhoods; instead, an ego-centred approach was used whereby individual neighbourhood measures were computed for each child's residential and school locations.[24] Moreover, no evidence of spatial autocorrelation resulting from the dependency of properties within geographic spaces was found, indicating that nearby entities did not share more similarities than entities that were further apart (data not shown).

Unadjusted associations among indicators of residential neighbourhood food environment and dietary outcomes were examined using logistic regression. Subsequently, multivariable associations were analyzed adjusting for child's age and sex, as well as for potential confounders, namely parental education, household income, residential neighbourhood material deprivation and residential population density (as a measure of level of urbanicity). For analyses involving school neighbourhoods, generalized estimating equations (GEE) with a logit link function and with an independent working correlation structure were used to allow for clustering of dietary outcomes among children attending the same schools. Multivariable GEE models were adjusted for child's age, sex, parental education, household income, school neighbourhood material deprivation and school neighbourhood population density. Given the high correlations between proximity-based indicators and between density-based indicators of each type of food establishment (r=0.7 to 0.9), each variable was examined in separate models for residential and school neighbourhoods using the "best access" (i.e., closest or densest tertile) as the reference category. For RFE indices, values below the cut-offs were used as the reference category. Odds ratios (OR) and 95% confidence intervals (CIs) are presented. All analyses were conducted using SAS, version 9.2 (Cary, NC).

In secondary analyses, we restricted the sample to children who lived >1.5 km from their school, i.e., those who were more likely to have distinct residential and school neighbourhood food environments, since there would be minimal overlap between respective 1 km network buffers centred on each location. Associations between the density of food establishments and dietary outcomes were examined in this subgroup in an attempt explore which of the residential or school neighbourhood food environment features were most strongly associated with dietary outcomes.

RESULTS

Overall, 34% of the 512 children consumed the recommended daily intake of ≥5 servings of V&F per day (average of 4.3 servings), 58% drank >50 mL of sugar-sweetened beverages daily, 44% had a meal/snack in a food establishment, and 35% consumed delivered/take-out foods at least once per week (Table 1). Overall, supermarkets, fast-food restaurants and convenience stores were more accessible around schools than around residences, as shown by shorter distances to and higher densities of each type of food establishment in school neighbourhoods. Thirty-eight percent (n=193) lived >1.5 km from their school.

Table 2. Covariate-adjusted Associations (OR and 95% CI) Between Measures of the Residential Neighbourhood Food Environment and Dietary Outcomes in the QUALITY Study*

	≥5 Servings of V&F/Day (n=493)§	>50 mL Sugar-sweetened Beverages/Day (n=493)	Eating/Snacking Out ≥Once/Week (n=506)	Delivered/Take-out Food ≥Once/Week (n=506)
Proximity measures				
Model 1 – distance to nearest supermarket				
Farthest (>2000 m)	1.09 (0.62-1.91)	0.82 (0.48-1.39)	1.04 (0.62-1.73)	0.96 (0.56-1.65)
Intermediate (965 to 2000 m)	1.07 (0.65-1.74)	0.84 (0.52-1.35)	1.12 (0.71-1.77)	1.47 (0.92-2.36)
Shortest (<965 m)	1	1	1	1
Model 2 – distance to nearest fast-food restaurant				
Farthest (>1835 m)	1.39 (0.81-2.40)	0.82 (0.49-1.37)	1.03 (0.63-1.68)	1.03 (0.61-1.73)
Intermediate (940 to 1835 m)	1.27 (0.77-2.10)	0.98 (0.61-1.58)	1.08 (0.69-1.71)	1.40 (0.87-2.24)
Shortest (<940 m)	1	1	1	1
Model 3 – distance to nearest convenience store				
Farthest (>1090 m)	0.99 (0.57-1.72)	0.85 (0.50-1.44)	1.15 (0.70-1.90)	0.93 (0.55-1.56)
Intermediate (545 to 1090 m)	0.98 (0.59-1.63)	0.87 (0.54-1.40)	1.23 (0.78-1.96)	1.02 (0.63-1.64)
Shortest (<545 m)	1	1	1	1
Density measures				
Model 4 – density of supermarkets				
Lowest	1.11 (0.63-1.93)	1.20 (0.70-2.05)	0.63 (0.37-1.05)‡	0.91 (0.53-1.58)
Intermediate	0.87 (0.52-1.48)	1.38 (0.84-2.29)	0.78 (0.48-1.26)	1.40 (0.85-2.29)
Highest	1	1	1	1
Model 5 – density of fast-food restaurants				
Lowest	1.22 (0.68-2.22)	1.19 (0.67-2.11)	0.52 (0.30-0.91) †	1.11 (0.63-1.98)
Intermediate	1.01 (0.59-1.74)	1.24 (0.74-2.08)	0.60 (0.36-0.99)†	1.10 (0.66-1.84)
Highest	1	1	1	1
Model 6 – density of convenience stores				
Lowest	1.02 (0.55-1.91)	1.25 (0.69-2.27)	0.44 (0.25-0.80)†	0.93 (0.51-1.70)
Intermediate	1.17 (0.68-2.04)	1.19 (0.70-2.03)	0.60 (0.36-1.02) ‡	1.15 (0.68-1.95)
Highest	1	1	1	1
Retail food environment measures				
Model 7 – 1 km buffer RFE Index				
≥2 (27.3%)	0.90 (0.58-1.42)	0.93 (0.61-1.43)	1.01 (0.67-1.52)	1.35 (0.89-2.05)
<2 (72.7%)	1	1	1	1
Model 8 – 3 km buffer RFE Index				
≥2.5 (26.2%)	0.77 (0.49-1.21)	0.94 (0.62-1.44)	0.88 (0.59-1.33)	1.22 (0.80-1.87)
<2.5 (73.8%)	1	1	1	1

* Separate logistic regression models for each main exposure and each outcome, adjusted for child's age, sex, parental education, household income, residential neighbourhood material deprivation and residential population density.

§ When treated as a continuous outcome, farthest (vs. shortest) distance to the nearest fast-food restaurant was associated with V&F intake (Beta=0.50, 95% CI: 0, 1.00); and 3 km RFE index ≥2.5 (vs. less) was associated with V&F intake (Beta=-0.40, 95% CI: -0.81, 0.005).

† p≤0.05; ‡p≤0.10.

OR=odds ratio; CI=confidence interval; V&F=vegetables and fruit; RFE=retail food environment.

Tables 2 and 3 show covariate-adjusted associations of proximity, density and retail food environment measures with children's dietary outcomes for both residential and school neighbourhood environments respectively. Living in a residential neighbourhood with a lower density of fast-food restaurants was associated with a 48% (OR=0.52, 95% CI: 0.30-0.91) and 40% (OR=0.60, 95% CI: 0.36-0.99) lower likelihood of eating/snacking out, for lowest and intermediate densities respectively. Similar associations were found for convenience stores, the lowest density compared with the highest density indicating a 56% (OR=0.44, 95% CI: 0.25-0.80) lower likelihood of eating/snacking out. Residential neighbourhood proximity-based indicators were not associated with children's diets, nor were residential RFE indices. Access to food establishments in the school environment was only marginally associated with dietary outcomes (Table 3). For example, intermediate (vs. shortest) distance between attended school and the nearest fast-food restaurant was associated with an increased likelihood of consuming recommended servings of V&F (p=0.08). Similarly, attending schools in neighbourhoods with the lowest density of supermarkets (vs. highest density) was associated with a decreased likelihood of eating/snacking out (p=0.08); an intermediate density of supermarkets (vs. highest density) was associated with an increased likelihood of consuming sugar-sweetened beverages (p=0.07); and intermediate density of fast-food restaurants (vs. highest density) was associated with an increased likelihood of consuming delivered/take-out foods (p=0.09).

The residential neighbourhood RFE indices were not associated with dietary outcomes (Table 2). Attending a school in a neighbourhood with a 3 km buffer RFE Index ≥2.5 (i.e., 2.5 fast-food restaurants/convenience stores for 1 supermarket/specialty store) was associated with a 61% (OR=1.61, 95% CI: 1.01-2.56) greater likelihood of consuming sugar-sweetened beverages, after adjustment for individual and neighbourhood covariates (Table 3). Similarly, an elevated RFEI within 1 and 3 km buffers around schools was marginally associated with a lower likelihood of consuming recommended servings of V&F.

Among children living >1.5 km from their school, lowest (vs. highest) school neighbourhood density of fast-food restaurants was associated with a higher likelihood of consuming recommended servings of V&F, and intermediate (vs. highest) school neighbourhood density of fast-food restaurants was associated with a higher likelihood of consuming delivered/take-out food (Table 4). The residential density of convenience stores remained positively associated with eating/snacking out.

Last, when V&F intake was treated as a continuous variable using linear regression models, children living farthest from fast-food restaurants had a 0.5 additional serving of V&F daily (β=0.50, 95% CI: 0, 1.00) compared with those living at the shortest distance. Moreover, living in or attending a school in a neighbourhood with 3 km RFE indices ≥2.5 was associated with up to a half serving less of V&F (β=-0.40, 95% CI: -0.81, 0.005 for residential neighbourhood and β=-0.50, 95% CI: -0.91, -0.09 for school neighbourhood).

Table 3. Covariate-adjusted Associations (OR and 95% CI) Between Measures of the School Neighbourhood Food Environment and Dietary Outcomes in the QUALITY Study*

	≥5 Servings of V&F/Day (n=489)§	>50 mL Sugar-sweetened Beverages/Day (n=489)	Eating/Snacking Out ≥Once/Week (n=502)	Delivered/Take-out Food ≥Once/Week (n=502)
Proximity measures				
Model 1 – Distance to nearest supermarket				
Farthest (>1565 m)	1.03 (0.63-1.68)	0.93 (0.56-1.55)	1.05 (0.67-1.65)	1.14 (0.70-1.86)
Intermediate (670 to 1565 m)	1.26 (0.77-2.06)	1.00 (0.62-1.62)	1.20 (0.79-1.81)	1.14 (0.73-1.78)
Shortest (<670 m)	1	1	1	1
Model 2 – Distance to nearest fast-food restaurant				
Farthest (>1460 m)	1.18 (0.66-2.10)	0.87 (0.51-1.48)	1.23 (0.79-1.94)	1.34 (0.84-2.14)
Intermediate (680 to 1460 m)	1.59 (0.95-2.64)‡	0.77 (0.48-1.23)	1.39 (0.89-2.17)	1.22 (0.77-1.93)
Shortest (<680 m)	1	1	1	1
Model 3 – Distance to nearest convenience store				
Farthest (>834 m)	1.13 (0.66-1.91)	0.99 (0.58-1.68)	1.10 (0.69-1.77)	1.08 (0.68-1.71)
Intermediate (370 to 835 m)	1.10 (0.68-1.81)	1.48 (0.91-2.39)	0.94 (0.61-1.47)	0.69 (0.43-1.10)
Shortest (<370 m)	1	1	1	1
Density measures				
Model 4 – Density of supermarkets				
Lowest	0.99 (0.55-1.78)	1.37 (0.74-2.51)	0.63 (0.37-1.06)‡	0.97 (0.56-1.67)
Intermediate	0.82 (0.49-1.35)	1.64 (0.96-2.79)‡	0.78 (0.48-1.28)	1.55 (0.91-2.64)
Highest	1	1	1	1
Model 5 – Density of fast-food restaurants				
Lowest	1.59 (0.85-2.94)	0.97 (0.54-1.75)	0.85 (0.50-1.47)	1.25 (0.71-2.20)
Intermediate	1.25 (0.69-2.25)	1.06 (0.64-1.76)	0.96 (0.58-1.57)	1.53 (0.93-2.50)‡
Highest	1	1	1	1
Model 6 – Density of convenience stores				
Lowest	1.34 (0.69-2.60)	1.04 (0.56-1.93)	0.71 (0.38-1.35)	0.75 (0.41-1.35)
Intermediate	1.39 (0.80-2.41)	0.98 (0.59-1.61)	0.81 (0.47-1.41)	1.03 (0.61-1.73)
Highest	1	1	1	1
Retail food environment measures				
Model 7 – 1 km buffer RFE Index				
≥2 (21.9%)	0.63 (0.39-1.04)‡	0.96 (0.60-1.51)	0.74 (0.47-1.15)	0.93 (0.61-1.41)
<2 (78.1%)	1	1	1	1
Model 8 – 3 km buffer RFE Index				
≥2.5 (22.9%)	0.67 (0.41-1.08)‡	1.61 (1.01-2.56)†	0.83 (0.53-1.30)	1.25 (0.81-1.91)
<2.5 (77.1%)	1	1	1	1

* Separate GEE (generalized estimating equations) model with logit link function for each main exposure and each outcome, adjusted for child's age, sex, parental education, household income, school neighbourhood material deprivation and school neighbourhood population density.
†p≤0.05; ‡p≤0.10.
§ When treated as a continuous outcome, 3 km RFE Index ≥2.5 (vs. less) was associated with V&F intake (Beta=-0.50, 95% CI: -0.91, -0.09).
OR=odds ratio; CI=confidence interval; V&F=vegetables and fruit; RFE=retail food environment.

DISCUSSION

We examined associations between indicators of neighbourhood food environments and dietary outcomes among children with a family history of obesity. The findings suggest that the availability of fast-food restaurants and convenience stores in children's neighbourhood environments may be associated with their intake of V&F, and the likelihood of eating/snacking out and consuming delivered/take-out foods. This extends recent research on built environments and children's diets. Although associations tended to be weak in magnitude, observed associations are overall consistent with current research on obesogenic environments and health.

As previously reported,[5-7] we found no consistent associations between a greater availability of supermarkets and more favourable dietary outcomes. Supermarkets typically offer a large variety of healthful foods, including vegetables and fruits, at lower costs.[25] However, there appear to be very few "food deserts" in Montreal, i.e., neighbourhoods where residents are considered to have poor access to supermarkets.[26] Associations between the availability of supermarkets and diets may be more likely to emerge in areas with less equitable distributions of supermarkets and may be more relevant to adult populations. In contrast to supermarket availability, we found more evidence that the availability of fast-food restaurants and convenience stores was associated with children's diets, particularly with the likelihood of eating or having a snack in a food establishment. These findings suggest that easy access to unhealthful foods may be more of a concern than poor access to more healthful foods.[27]

Geographic clustering of fast-food restaurants and convenience stores around schools has been described previously,[14] although our findings suggest that associations between access to these food establishments and children's diets were more consistent for residential than for school neighbourhood exposures. This may be related to the relatively young age of participants; school neighbourhoods may become more important during adolescence, when students attending secondary school are typically authorized to leave school grounds.[28]

Use of the RFE indices revealed that children residing in or attending a school in neighbourhoods with a preponderance of unhealthful food establishments scored most poorly on dietary outcomes.[29] An indicator of relative access to types of food establishments is a useful complement to proximity- and density-based indicators, as commercial destinations tend to be geographically clustered such that higher numbers of fast-food restaurants are often associated with more supermarkets and fruit and vegetable stores as well.

Restricting analyses to the subgroup of children living >1.5 km from their school allowed us to partially distinguish associations with residential neighbourhood environments from associations with school neighbourhood environments. However, the results of these subanalyses are likely not generalizable to the entire sample. In this subgroup, children who lived farther away from their school were more likely to be driven to or from their school than to travel by bus. A higher likelihood of car travel may lead to more oppor-

Table 4. Covariate-adjusted Associations (OR and 95% CI) of Residential and School Neighbourhood Densities of Food Establishments with Dietary Outcomes in Children Living More Than 1.5 km From Their School, QUALITY Study

	≥5 Servings of V&F/Day (n=189)	>50 mL Sugar-sweetened Beverages/Day (n=189)	Eating/Snacking Out ≥Once/Week (n=191)	Delivered/Take-out Food ≥Once/Week (n=191)
Residential environment*				
Model 1 – Density of supermarkets				
Lowest	1.01 (0.38-2.69)	1.00 (0.38-2.63)	0.66 (0.25-1.72)	1.27 (0.44-3.66)
Intermediate	0.79 (0.33-1.88)	1.32 (0.56-3.12)	0.70 (0.30-1.63)	2.13 (0.86-5.31)‡
Highest	1	1	1	1
Model 2 – Density of fast-food restaurants				
Lowest	0.91 (0.32-2.53)	1.69 (0.62-4.64)	0.67 (0.25-1.79)	3.45 (1.10-10.84)†
Intermediate	0.67 (0.27-1.65)	1.22 (0.51-2.95)	0.79 (0.34-1.87)	1.81 (0.70-4.73)
Highest	1	1	1	1
Model 3 – Density of convenience stores				
Lowest	0.71 (0.24-2.08)	1.53 (0.53-4.40)	0.32 (0.11-0.93)†	1.78 (0.57-5.60)
Intermediate	0.56 (0.21-1.45)	1.45 (0.57-3.69)	0.41 (0.16-1.05)‡	1.67 (0.62-4.51)
Highest	1	1	1	1
School environment**				
Model 4 – Density of supermarkets				
Lowest	1.70 (0.63-4.60)	0.72 (0.28-1.88)	0.76 (0.31-1.90)	0.80 (0.26-2.48)
Intermediate	1.06 (0.49-2.30	1.01 (0.45-2.26)	1.17 (0.54-2.53)	1.49 (0.60-3.71)
Highest	1	1	1	1
Model 5 – Density of fast-food restaurants				
Lowest	2.87 (1.16-7.10)†	1.04 (0.46-2.37)	1.63 (0.70-3.82)	1.51 (0.58-3.93)
Intermediate	0.87 (0.34-2.21)	1.31 (0.54-3.19)	1.76 (0.83-3.72)	2.84 (1.16-6.97)†
Highest	1	1	1	1
Model 6 – Density of convenience stores				
Lowest	2.21 (0.76-6.47)	0.58 (0.20-1.68)	1.26 (0.47-3.35)	0.53 (0.16-1.81)
Intermediate	0.93 (0.37-2.37)	0.70 (0.25-1.92)	1.19 (0.53-2.69)	0.98 (0.32-3.04)
Highest	1	1	1	1

* Separate logistic regression models for each exposure and each outcome, adjusted for child's age, sex, parental education, household income, residential neighbourhood material deprivation and residential population density.
** Separate GEE (generalized estimating equations) models with logit link function for each exposure and each outcome, adjusted for child's age, sex, parental education, household income, school neighbourhood material deprivation and school neighbourhood population density.
†p≤0.05, ‡p≤0.10.
OR=odds ratio; CI=confidence interval; V&F=vegetables and fruit.

tunistic purchases by parents, including those at drive-through restaurants, given the extended potential path area.[9,30] This may, in part, explain the higher fast-food intake among children living farther away from fast-food restaurants.

Initiatives to create zones around schools with limited access to fast-food restaurants and convenience stores have been proposed.[31] Such initiatives may have a positive impact on children's diet, particularly in the context of ecological interventions in which multiple levels of obesogenic environments are targeted. Although school neighbourhoods might be more compelling targets, policies to limit access to unhealthful food establishments in residential neighbourhoods should be further investigated.

The strengths of this study include the use of a valid and reliable method to measure children's diet and the use of objective measures to characterize neighbourhood food environments. Overall, the findings should be interpreted with caution, given the number of associations tested and the increased risk of type-1 error. The results should thus be seen as exploratory and in need of confirmation in future studies. Other limitations include the possibility that children with certain dietary patterns were self-selected through their parents to reside in neighbourhoods with particular food establishment profiles. Moreover, because the majority of children lived within a short walking distance of their school, it was not possible to distinguish entirely between the associations of residential vs. school neighbourhood environments with children's diets. While we used a GIS to quantify the availability of various types of food establishment,[32] others have used measures of perceived access.[33] Parents and children may incorporate aspects other than local availability to formulate perceptions of access, such as car ownership, parental permissiveness and available pocket money; this should be examined in future research that includes both GIS and perceived measures. Last, since the children in this study were relatively young (8-10 years), associations of interest may be mediated and/or confounded by parental diet; however, there were no measures of parent diet in the QUALITY study. Maternal BMI was considered as a proxy for mother's diet, but was not retained because its inclusion in the models did not change main exposure coefficients substantively and because the study design required at least one parent to be obese.

In conclusion, our findings suggest that among children aged 8-10 years, residential neighbourhood food environments are more strongly associated with dietary outcomes than are school neighbourhood food environments. Although the magnitude of associations is relatively small, the potential to affect population dietary behaviours and related health outcomes may be substantial. Frequent and widespread food purchasing opportunities within children's environments may be one factor amenable to interventions to improve diets.

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RÉSUMÉ

Objectifs : Rares sont les études du milieu bâti qui s'intéressent aux environnements alimentaires des quartiers par rapport aux régimes alimentaires des enfants. Nous avons examiné les associations entre l'accès des quartiers résidentiels et scolaires à différents types d'établissements alimentaires et les régimes des enfants.

Méthode : Nous avons analysé les données de l'étude QUALITY (QUebec Adipose and Lifestyle InvesTigation in Youth), une étude en cours sur l'histoire naturelle de l'obésité chez 630 jeunes Québécois de 8 à 10 ans ayant une histoire parentale d'obésité (n=512). Trois rappels alimentaires de 24 heures ont servi à évaluer l'apport en fruits et légumes et en boissons édulcorées au sucre. À l'aide de questionnaires, nous avons déterminé la fréquence des repas et des collations pris à l'extérieur et la consommation d'aliments livrés à domicile ou à emporter. Nous avons caractérisé l'environnement alimentaire des quartiers résidentiels et scolaires au moyen d'un système d'information géographique. Les variables étaient la distance jusqu'au supermarché, au restaurant rapide et au dépanneur le plus proche, et les densités de chacun de ces types d'établissements, calculées sur un réseau tampon d'1 km autour du domicile et de l'école de chaque enfant. Des indices d'environnement alimentaire de détail ont aussi été calculés. La régression logistique multivariée (accès à partir du domicile) et des équations d'estimation généralisées (accès à partir de l'école) ont servi à l'analyse.

Résultats : L'accès des quartiers résidentiels et scolaires aux supermarchés n'était pas associé aux régimes des enfants. Le fait d'habiter un quartier où les restaurants rapides et les dépanneurs sont moins accessibles était associé à une plus faible probabilité de prendre des repas et des collations à l'extérieur. Les enfants qui fréquentaient des écoles de quartiers comptant davantage d'établissements alimentaires malsains que d'établissements sains ont obtenu les pires scores pour ce qui est de leur régime.

Conclusions : Des enquêtes plus poussées sont nécessaires pour formuler des politiques qui influencent les occasions d'achat d'aliments à l'échelle des quartiers, particulièrement l'accès aux restaurants rapides et aux dépanneurs.

Mots clés : milieu bâti; enfant; régime alimentaire; environnement alimentaire; quartier résidentiel; quartier scolaire; cohorte QUALITY