

The association between overweight and opportunity structures in the built environment: a multi-level analysis among elementary school youth in the PLAY-ON study

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Abstract

Objective To examine school-level opportunity structures of the built environment and student characteristics associated with being overweight.

Methods Multi-level logistic regression analysis were used to examine the school- and student-level characteristics associated with the odds of a student being overweight among grade 5–8 students attending 30 elementary schools in Ontario, Canada, as part of the Play-Ontario (PLAY-ON) study.

Results Significant between school random variation in overweight was identified [$\sigma^2_{\mu_0} = 0.187 (0.084)$, $P < 0.001$]; school-level differences accounted for 5.4% of the variability in the odds of a student being overweight. The more fast-food retailers there were surrounding a school, the more

likely a student was to be overweight; students in grade 5 were at increased risk relative to students in grades 6–8. The more grocery stores there were surrounding a school, the more likely a student was to be overweight; students in grade 5 were at increased risk relative to students in grades 6–8.

Conclusions Developing a better understanding of the school- and student-level characteristics associated with overweight among youth is critical for informing intervention programs and policies.

Keywords Obesity/overweight ·

Body mass index (BMI) · Built environment ·
Physical activity · Prevention · Youth · School

Introduction

The prevalence of overweight youth in North America has increased dramatically (Shields 2006; Ogden et al. 2006). This is cause for concern as overweight among youth is not only associated with hypertension and abnormal glucose tolerance (ADA 2006), but it is also associated with increased risk of some cancers (Colditz et al. 1996). Given the rapid increase in the prevalence of overweight among youth, it appears that modifiable factors [e.g. physical activity (PA), diet] are likely more important determinants of the current crisis than non-modifiable factors (e.g. genetics) (Anderson and Butcher 2006). Considering ~83% of overweight youth will maintain an unhealthy weight as adults (Herman et al. 2009), there is an immediate need to identify the factors associated with youth overweight in order to develop effective prevention initiatives.

Research has previously identified a number of individual characteristics that are associated with overweight

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among youth. For instance, overweight youth are less likely to be physically active (Leatherdale and Papadakis 2009; Singh et al. 2010; Storey et al. 2003), less likely to have active friends (Trost et al. 2001), more likely to spend time in sedentary behaviours (Leatherdale and Papadakis 2009; Singh et al. 2010; Cecil-Karb and Grogan-Kaylor 2009), more likely to be male (Leatherdale and Papadakis 2009; Grafova 2008; Ewing et al. 2006) and be non-white ethnicity (Cecil-Karb and Grogan-Kaylor 2009; Ewing et al. 2006). Although research has identified that dietary factors are associated with overweight among adolescents, data from the Continuing Survey of Food Intake for Individuals (CSFII) and the National Health and Nutrition Examination Survey III (NHANES) suggest that dietary factors are not strongly associated with overweight in children (Storey et al. 2003).

The neighbourhood environment surrounding a school can play an important role in providing students with opportunities to engage in activities that help to prevent or reduce overweight. For instance, students are less likely to be overweight if their school neighbourhood has access to parks, playgrounds, recreational facilities, shops with modestly priced fresh produce (Veugelers et al. 2008) and large chain supermarkets (Powell et al. 2007), whereas students are more apt to be overweight if there are variety stores or fast-food restaurants located near their school (Davis and Carpenter 2009; Powell et al. 2007). However, few studies have examined how the prevalence of overweight varies across schools and the characteristics of the built environment surrounding a school that are associated with that variability (O'Malley et al. 2007). Existing evidence suggests that there is modest variability in overweight across secondary schools (Leatherdale and Papadakis 2009; Veugelers et al. 2008; O'Malley et al. 2007; Singh et al. 2007), while there is substantially less research examining the between-school variability in overweight across elementary school settings (Seliske et al. 2009; Veugelers et al. 2008). The lack of evidence exploring how opportunity structures in the community environment surrounding elementary schools are associated with an individual student's risk of being overweight continues to represent an important gap in the literature.

As such, the current study seeks to: (1) characterize the prevalence of weight status in a sample of elementary school students, (2) characterize the prevalence of different opportunity structures of the built environment surrounding 30 elementary schools, (3) identify potential variability in the odds of being overweight across schools and (4) explore if student- and school-level characteristics are associated with overweight/obesity in grades 5–8 students.

Methods

Design

This cross-sectional study used self-reported data collected in 2007–2008 from a convenience sample of grades 5–8 students attending 30 elementary schools in Ontario, Canada, as part of the Play-Ontario (PLAY-ON) study. The purpose of PLAY-ON was to examine the school-level factors associated with PA and obesity among a sample of elementary school aged youth. Student-level data were collected from consenting students using the SHAPES Physical Activity Module (PAM). The PAM asks students about PA, height and weight, sedentary behaviours and correlates for PA. Validity testing has previously demonstrated significant criterion validity based on Spearman correlations for the self-reported measures of height ($r = 0.97$, $P < 0.001$), weight ($r = 0.98$, $P < 0.001$) and PA ($r = 0.44$, $P < 0.01$), and reliability testing has demonstrated 1-week test–retest reliability based on weighted kappa coefficients for the self-reported BMI ($K = 0.75$, $P < 0.01$) and PA ($K = 0.58$, $P < 0.05$) (Wong et al. 2006). Additional details are available online (www.shapes.uwaterloo.ca/projects/PLAYON) or in print (Leatherdale et al., 2009, 2010).

School-level built environment data were provided by the CanMap RouteLogistics (CMRL) spatial information database as well as the Enhanced Points of Interest (EPOI) data resource from the Desktop Mapping Technologies Inc. (DMTI). The CMRL provided various data layers such as boundary files and street networks. The DMTI-EPOI data file is a database of the type and location of different opportunity structures within the built environment (e.g. grocery stores, mini-marts, fast-food restaurants, fitness centres). Additional details about the DMTI-EPOI resources are available online (www.dmtispacial.com).

Data collection

All students at the participating schools were eligible to participate. Prior to participating, active consent from parents was required, and at any time, students were able to decline participation. The PAM was completed by eligible students during class time, and there was no compensation for participation. The University of Waterloo Office of Research Ethics and appropriate school board ethics committees approved the study procedures.

Participants

Of the 4,838 students enrolled in grades 5–8 at the 30 participating elementary schools, 50.6% ($n = 2,449$)

completed the survey. Missing respondents resulted from parent refusal (46.2%; $n = 2,237$) and absenteeism on the day of the survey (3.2%; $n = 152$). This distribution is consistent with an active consent study examining overweight among Canadian elementary students (Veuglers and Fitzgerald 2005). Among participating students, BMI could not be calculated for 48.4% ($n = 1,185$) of the sample due to missing data required to calculate BMI, 16.2% ($n = 398$) did not report their height and weight, 22.8% ($n = 558$) reported their weight but not height, 8.0% ($n = 196$) reported their height but not weight and 1.3% ($n = 33$) did not report their age. Previous studies among youth have reported similar rates of missing height and weight data (Tiggemann 2006).

Outcome—weight status

Body Mass Index (BMI) was calculated using previously validated self-report measures of weight (kg) and height (m) ($BMI = kg/m^2$) (Wong et al. 2006). Consistent with CDC guidelines and growth charts (CDC, 2006), students within the lowest 5th percentile for BMI adjusted for age and sex were classified as underweight, students within the 6th to 84th percentile for BMI adjusted for age and sex were classified as normal weight, students within the 85th to 94th percentile for BMI adjusted for age and sex were classified as overweight and students within the highest 5th percentile for BMI adjusted for age and sex were classified as obese. For the multivariate analyses, students classified as overweight or obese were collapsed into one category (*overweight*) to represent all youth who may be at-risk for morbidity associated with being overweight/obese and to ensure there was sufficient power for the multi-level analyses.

Student-level correlates

Using previously validated measures (Wong et al. 2006), PA level was measured by asking respondents how many minutes of vigorous PA (VPA) and moderate PA (MPA) they engaged in on each of the last 7 days. Since youth tend to substantially over report time spent doing PA in self-report (McMurray et al. 2004), the measures are more valid for differentiating students who report less time doing PA from those who report more time doing PA (Wong et al. 2006). Hence, consistent with the existing literature (Leatherdale et al. 2010; Leatherdale and Wong 2008), students more than one standard deviation (≤ 16 th percentile) below the sample mean were classified as low active, students more than one standard deviation (≥ 84 th percentile) above the sample mean were classified as highly active; all others were classified as moderately active.

Consistent with previous research (Leatherdale et al. 2010; Kurc and Leatherdale 2009), sedentary behaviour was measured by asking respondents to report the number of hours for each day of the week that they spent watching TV/movies, playing video/computer games, surfing the internet, instant messaging, texting or talking on the phone. Based on the average time reported for these behaviours over the previous week, respondents with less than 1 h per day were classified as low sedentary, those with between 1 and 3 h were classified as moderate sedentary, and students with more than 3 h per day were classified as high sedentary. Respondents also reported their ethnicity (white vs. other), how many of their close friends are physically active (0–5) and whether they consider themselves overweight, about the right weight or underweight.

School-level built environment characteristics

The 2008 DMTI-EPOI data were used to identify opportunity structures within the neighbourhood surrounding the 30 PLAY-ON elementary schools. For this study, there were six different types of opportunity structures examined: gas stations, fast-food retailers, bakeries/doughnut shops, variety stores, grocery stores (includes supermarkets and mini-markets) and recreation facilities (includes dance studios, fitness/gym facilities, and sport and recreation clubs). Consistent with previous research (Pouliou and Elliott 2010), the process of identifying and linking the DMTI-EPOI data to the PLAY-ON student-level data involved three steps: (1) geocoding the address for each PLAY-ON school; (2) creating 1-km circular buffers (i.e. bounded areas surrounding each school in which the six different opportunity structures of the built environment were quantified) and (3) linking the quantified built environment data for each school to the student-level data from each school. Arcview 3.3 (ESRI 2002) software was used to geocode the school addresses and to create the 1-km buffers.

Analyses

Using student-level data, the prevalence of weight status, ethnicity, grade, PA, sedentary behaviour and the number of close friends who are active were examined by sex. Using the school-level data, we calculated the mean and range of each school-level built environment characteristic. Since students (level 1) are nested within schools (level 2), a series of multi-level logistic regression analyses were performed in order to understand the student- and school-level factors associated with being overweight within this hierarchical data structure. Consistent with other multi-level studies (Leatherdale et al. 2010; Murnaghan et al. 2007), a three-step modelling procedure was used. Step 1

examined if differences in being overweight were random or fixed across schools. The school-level variance term from Step 1 ($\sigma_{\mu 0}^2$) was used to calculate the intraclass correlation (ICC) for binary outcomes, where the ICC represents the proportion of the total variance in student overweight that is due to differences across schools. In Step 2, a series of six univariate analyses were performed to examine if each school-level built environment opportunity structure was independently associated with being overweight (Models 1–6). In Step 3, a multivariate model was developed to simultaneously examine how the student-level characteristics and the school-level characteristics were associated with being overweight (Final Model). Because cross-level interactions between the school-level variables and grade and sex were suspected a priori, these cross-level interactions were also tested while controlling for confounders. Since there was a large amount of missing BMI data, we also performed sensitivity analyses by imputing some of the missing BMI data. Research with the PLAY-ON previously identified that students were more likely to have missing BMI data if they perceived themselves to be overweight or if they were considered low active and highly sedentary (Arbour-Nicitopoulos et al. 2010). As such, among the respondents with missing BMI data, we identified those who reported that they consider themselves overweight ($n = 244$) and those who were low active and highly sedentary ($n = 552$). In a new model (Sensitivity Model), these 796 respondents were coded as being overweight and grouped with the respondents who did provide BMI data and were considered overweight. The remaining 389 respondents with missing data who did not consider themselves overweight or who were active or not highly sedentary were coded as being normal weight and included with the respondents who did provide BMI data and were considered a normal weight. Statistical analyses were conducted on MLwiN Version 2.02 (Rasbash et al. 2005).

Results

Student characteristics

Demographic characteristics of students who provided BMI data are presented in Table 1. The sample was 47.4% ($n = 1,152$) male and 52.6% ($n = 1,277$) female. The mean BMI among males was 19.5 (± 3.8) kg/m² and among females was 19.1 (± 4.1) kg/m². Moreover, 4.5% of the sample was considered underweight, 17.4% of the sample was considered overweight, 9.7% of the sample was considered obese and 68.4% were considered normal weight for their age and sex. Males were more likely to be overweight or obese compared to females ($\chi^2 = 12.46$, $df = 3$,

$P < 0.01$). A total of 166 (13.1%) students were classified as low active, 845 (66.9%) were classified as moderately active and 253 (20.0%) were classified as highly active. Males were more likely to be high active compared to females ($\chi^2 = 17.53$, $df = 2$, $P < 0.001$). The majority of students (63.9%) reported 1–3 h of sedentary behaviour time per day. Males were more likely than females to report spending 3 or more hours per day in sedentary activities ($\chi^2 = 12.17$, $df = 2$, $P < 0.01$). Few students reported that they have less than three close friends who are physically active (8.6%). Males were more likely than females to report having five close friends who are active ($\chi^2 = 38.41$, $df = 5$, $P < 0.001$).

School characteristics

The mean number of gas stations within a 1-km buffer of the schools was 0.53 (range 0–3). The mean number of fast-food retailers within a 1-km buffer of the schools was 1.7 (range 0–8). The mean number of bakeries/doughnut shops within a 1-km buffer of the schools was 1.1 (range 0–8). The mean number of variety stores within a 1-km buffer of the schools was 1.3 (range 0–8). The mean number of grocery stores within a 1-km buffer of the schools was 1.8 (range 0–13). The mean number of recreation facilities within a 1-km buffer of the schools was 0.8 (range 0–4).

School characteristics associated with overweight

Among students without missing BMI data, significant between-school random variation in the odds of being overweight was identified [$\sigma_{\mu 0}^2 = 0.187$ (0.084), $P < 0.001$]; school-level differences accounted for 5.4% of the variability in the odds of a student being overweight versus a normal weight. As shown in Table 2, none of the school-level opportunity structures in the built environment surrounding schools were significantly associated with the likelihood of a student being overweight.

School- and student-level characteristics associated with overweight

The adjusted odds ratios for the significant school and student characteristics in the Final Model are presented in Table 3. Male students were more likely to be overweight than female students (OR 1.68; 95% CI 1.27–2.21). Compared to students in grade 5, students in grade 7 (OR 0.59; 95% CI 0.39–0.89) and grade 8 (OR 0.57; 95% CI 0.38–0.86) were less likely to be overweight. Students who were highly active were less likely to be overweight compared to low active students (OR 0.73; 95% CI 0.69–0.76). Sedentary behaviour, ethnicity, and having

Table 1 Descriptive statistics for youth in grades 5–8 who provided data to calculate body mass index (BMI) by gender in PLAY-ON (Ontario, Canada, 2007–2008)

| Student-level characteristics | Male (<i>n</i> = 663) % (<i>n</i>) ^a | Female (<i>n</i> = 601) % (<i>n</i>) ^a | χ^2 |
|--|---|---|-------------------------------------|
| Weight status^b | | | |
| Underweight | 4.4 (29) | 4.7 (28) | $\chi^2 = 43.24, df = 3, P < 0.001$ |
| Normal weight | 64.5 (428) | 72.7 (437) | |
| Overweight | 19.3 (128) | 15.3 (92) | |
| Obese | 11.8 (78) | 7.3 (44) | |
| Physical activity level | | | |
| High active | 24.4 (162) | 15.1 (91) | $\chi^2 = 17.53, df = 2, P < 0.001$ |
| Moderately active | 63.8 (423) | 70.2 (422) | |
| Low active | 11.8 (78) | 14.6 (88) | |
| Screen time per day | | | |
| <1 h per day | 18.8 (124) | 24.3 (145) | $\chi^2 = 12.17, df = 2, P < 0.01$ |
| 1–3 h per day | 63.6 (419) | 64.2 (384) | |
| >3 h per day | 17.6 (116) | 11.5 (69) | |
| Number of close friends who are physically active | | | |
| None | 0.5 (3) | 0.0 (0) | $\chi^2 = 38.41, df = 5, P < 0.001$ |
| 1 | 1.8 (12) | 2.5 (15) | |
| 2 | 6.2 (40) | 6.2 (37) | |
| 3 | 13.9 (90) | 26.7 (159) | |
| 4 | 26.8 (174) | 25.4 (151) | |
| 5 | 50.8 (329) | 39.2 (233) | |
| Ethnicity | | | |
| Other | 34.8 (236) | 43.9 (275) | $\chi^2 = 11.50, df = 1, P < 0.001$ |
| White | 65.2 (443) | 56.1 (351) | |
| Grade | | | |
| 5 | 16.6 (110) | 14.3 (86) | $\chi^2 = 1.76, df = 3, P = 0.624$ |
| 6 | 23.4 (155) | 24.6 (148) | |
| 7 | 28.6 (190) | 30.6 (184) | |
| 8 | 31.4 (208) | 30.5 (183) | |

PLAY-ON represents the name of the study where self-reported data were collected in 2007–2008 from a convenience sample of grades 5–8 students attending 30 elementary schools in Ontario, Canada

^a Numbers may not add to total because of missing values

^b Body mass index (BMI) values used to determine weight status have been adjusted for age and gender

Table 2 Results of the univariate multi-level logistic regression analyses examining school-level built environment characteristics associated with being overweight among youth in grades 5–8 in PLAY-ON (Ontario, Canada, 2007–2008)

| Number of opportunity structures within a 1-km radius of a school | Odds ratio (95% confidence interval) overweight versus normal weight (each 1 unit increase) |
|---|---|
| Gas stations (Model 1) | 1.21 (0.99, 1.49) |
| Fast-food retailers (Model 2) | 1.06 (0.98, 1.16) |
| Bakeries/doughnut shops (Model 3) | 1.05 (0.95, 1.17) |
| Variety stores (Model 4) | 1.07 (0.97, 1.19) |
| Grocery stores (Model 5) | 1.06 (0.99, 1.13) |
| Recreation facilities (Model 6) | 1.16 (0.99, 1.37) |

1 = overweight (*n* = 342), 0 = normal weight (*n* = 865)

PLAY-ON represents the name of the study where self-reported data were collected in 2007–2008 from a convenience sample of grades 5–8 students attending 30 elementary schools in Ontario, Canada

close friends who were physically active were not significantly associated with being overweight. Consistent with the univariate analyses of Table 2, none of the school-level characteristics were significantly associated with overweight when controlling for student characteristics.

During the additional exploratory analyses, two significant contextual interactions were identified. As shown in Fig. 1, there was a significant interaction between grade and the number of fast-food retailers within a 1-km radius of the school. It appears that the more fast-food retailers there were surrounding a school, the more likely a student was to be overweight. However, the increase in risk is the largest among students in grade 5 relative to students in grades 6–8. Similarly, as shown in Fig. 2, there was also a significant interaction between grade and the number of grocery stores within a 1-km radius of the school. It appears that the more grocery stores there were surrounding a school, the more likely a student was to be overweight. However, the

Table 3 Odds ratios for multi-level analysis of school- and student-level factors associated with being overweight among youth in grades 5–8 in PLAY-ON (Ontario, Canada, 2007–2008)

| | Adjusted odds ratio ^a (95% CI) Final Model overweight versus normal weight |
|---|---|
| Student-level characteristics | |
| Gender | |
| Female | 1.00 |
| Male | 1.68 (1.27, 2.21)** |
| Grade | |
| 5 | 1.00 |
| 6 | 0.70 (0.46, 1.06) |
| 7 | 0.59 (0.39, 0.89)* |
| 8 | 0.57 (0.38, 0.86)** |
| Ethnicity | |
| Other | 1.00 |
| White | 0.94 (0.70, 1.25) |
| Physical activity level | |
| Low active | 1.00 |
| Moderately active | 1.02 (0.68, 1.53) |
| Highly active | 0.73 (0.69, 0.76)*** |
| Sedentary behaviour | |
| Low sedentary | 1.00 |
| Moderately sedentary | 0.92 (0.66, 1.30) |
| Highly sedentary | 1.07 (0.68, 1.70) |
| Number of close friends who are physically active | |
| None to 4 friends | 1.00 |
| All 5 friends | 1.01 (0.76, 1.32) |
| School-level characteristics | |
| Number of opportunity structures within a 1-km radius: each 1 unit increase | |
| Gas stations | 1.46 (0.79, 2.68) |
| Fast-food retailers | 0.96 (0.82, 1.13) |
| Bakeries/doughnut shops | 0.89 (0.68, 1.15) |
| Variety stores | 0.82 (0.59, 1.13) |
| Grocery stores | 1.10 (0.86, 1.42) |
| Recreation facilities | 1.18 (0.89, 1.56) |

Final Model: overweight
($n = 342$), 0 = normal weight
($n = 865$)

PLAY-ON represents the name of the study where self-reported data were collected in 2007–2008 from a convenience sample of grades 5–8 students attending 30 elementary schools in Ontario, Canada

* $P < 0.05$; ** $P < 0.01$;

*** $P < 0.001$

^a Odds ratios adjusted for all other variables in the table

increased risk is also the largest among students in grade 5 relative to students in grades 6–8.

Sensitivity analysis with imputed BMI values for missing data

As presented in Table 4, the results of the sensitivity analysis with the imputed BMI values are consistent with the results presented in Table 3. Highly active students and students in higher grades were less likely to be overweight, and sedentary behaviour, ethnicity, having close friends who were physically active, and the school-level characteristics were not significantly associated with being overweight. The main difference between the Final Model and the Sensitivity Model was that gender was no longer

significantly associated with being overweight in the sensitivity analysis model.

Discussion

Consistent with similar research (Veugelers et al. 2008; Veugelers and Fitzgerald 2005), we identified significant differences in the risk of being overweight across schools. Specifically, it was identified that school-level differences accounted for a significant amount of the variability in the odds of a student being overweight, suggesting that the characteristics of the school environment a student attends are associated with his/her risk of being overweight. We also identified that students in younger grades, especially

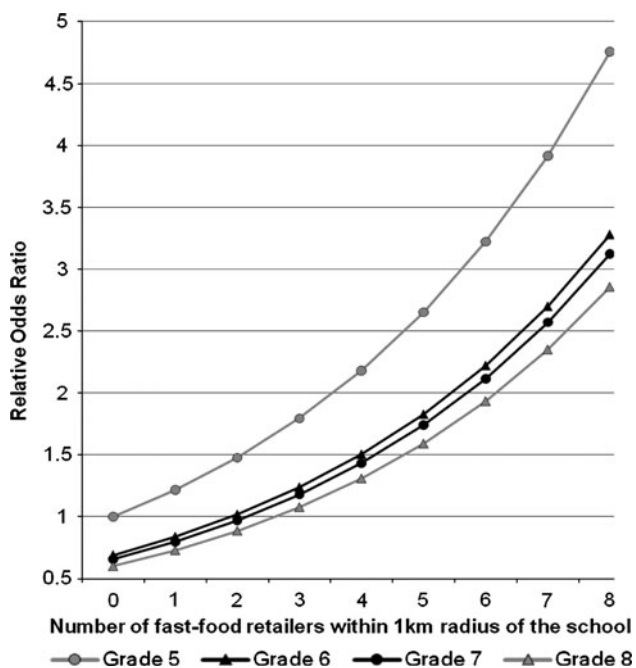


Fig. 1 Model-based estimated odds ratio for student being overweight as a function of the number of fast-food retailers within a 1-km radius of the school and the grade of the student in the PLAY-ON study (Ontario, Canada, 2007–2008). Using the model estimates, the odds of a student being overweight can be estimated as a function of both the number of fast-food retailers within a 1-km radius of the school and the grade of the student. In this figure, the model-based odds ratios of a student being overweight relative to a hypothetical grade 5 student who attends a hypothetical school with no fast-food retailers within a 1-km radius are presented. PLAY-ON represents the name of the study where self-reported data were collected in 2007–2008 from a convenience sample of grades 5–8 students attending 30 elementary schools in Ontario, Canada

grade 5, were at substantially increased risk for being overweight as the number of fast-food retailers or grocery stores located within a 1-km radius of their school increased. This finding is consistent with Davis and Carpenter (2009), who also found a positive relationship between children's BMI and the number of fast-food outlets surrounding schools. This suggests that it may be wise for stakeholders to target obesity prevention efforts to the schools that are placing students at the greatest risk (i.e. schools with a large number of fast-food retailers in the surrounding environment) and that such programs need to start at an early age when the students are at the greatest risk.

Contrary to our findings, Powell et al. (2007) found that chain supermarkets were related to lower BMI among youth, however, their ability to differentiate between chain supermarkets, non-chain supermarkets and grocery stores may explain the conflicting results. For instance, the ability to differentiate chain stores from non-chain stores may be important considering that the price of food plays a role in

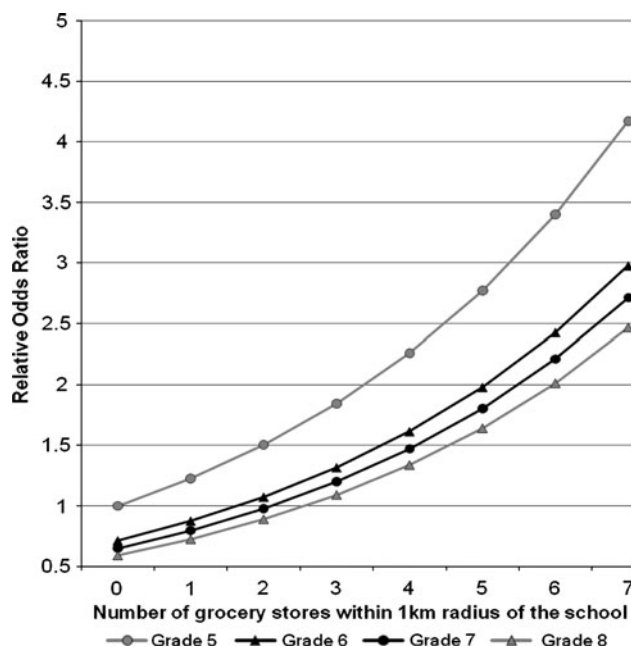


Fig. 2 Model-based estimated odds ratio for student being overweight as a function of the number of grocery stores within a 1-km radius of the school and the grade of the student in the PLAY-ON study (Ontario, Canada, 2007–2008). Using the model estimates, the odds of a student being overweight can be estimated as a function of both the number of grocery stores within a 1-km radius of the school and the grade of the student. In this figure, the model-based odds ratios of a student being overweight relative to a hypothetical grade 5 student who attends a hypothetical school with no grocery stores within a 1-km radius are presented. PLAY-ON represents the name of the study where self-reported data were collected in 2007–2008 from a convenience sample of grades 5–8 students attending 30 elementary schools in Ontario, Canada

youth overweight [e.g. BMI tends to be lower in children if they have access to moderately priced fresh produce (Veugelers et al. 2008)], and chain supermarkets may offer food at a lower cost than non-chain stores. When possible, measures related to monetary cost of food options within different establishments should be considered in future research. This insight could add substantial value as children in grades 4–6 overwhelmingly chose inexpensive, low-nutritive, energy dense food rather than more expensive yet much more nutritious alternatives (Borradaile et al. 2009).

We did not find a significant relationship between the presence of variety (convenience) stores and children's BMI nor between the presence of recreational facilities and BMI. This is in contrast to previous work (Singh et al. 2010; Galvez et al. 2009; Veugelers et al. 2008; Evenson et al. 2007; Grafova 2008; Powell et al. 2007). Since research has typically measured built environment characteristics relative to the students' home addresses rather than school location, this discrepancy is not surprising. As our focus is on identifying characteristics that can inform

Table 4 Odds ratios for the Sensitivity Model that included missing body mass index (BMI) values in the multi-level analysis of school- and student-level factors associated with being overweight among youth in grades 5–8 in PLAY-ON (Ontario, Canada, 2007–2008)

| | Adjusted odds ratio ^a (95% CI) Sensitivity Model ^b overweight versus normal weight |
|---|--|
| Student-level characteristics | |
| Gender | |
| Female | 1.00 |
| Male | 1.03 (0.86, 1.24) |
| Grade | |
| 5 | 1.00 |
| 6 | 0.72 (0.58, 0.96)* |
| 7 | 0.50 (0.39, 0.65)** |
| 8 | 0.35 (0.27, 0.46)** |
| Ethnicity | |
| Other | 1.00 |
| White | 0.94 (0.77, 1.14) |
| Physical activity level | |
| Low active | 1.00 |
| Moderately active | 1.18 (0.90, 1.54) |
| Highly active | 0.75 (0.58, 0.96)* |
| Sedentary behaviour | |
| Low sedentary | 1.00 |
| Moderately sedentary | 0.99 (0.79, 1.23) |
| Highly sedentary | 1.31 (0.96, 1.78) |
| Number of close friends who are physically active | |
| None to 4 friends | 1.00 |
| All 5 friends | 0.99 (0.82, 1.19) |
| School-level characteristics | |
| Number of opportunity structures within a 1-km radius: each 1 unit increase | |
| Gas stations | 1.04 (0.77, 1.43) |
| Fast-food retailers | 1.00 (0.92, 1.08) |
| Bakeries/doughnut shops | 0.94 (0.83, 1.07) |
| Variety stores | 0.99 (0.85, 1.16) |
| Grocery stores | 1.06 (0.93, 1.20) |
| Recreation facilities | 1.01 (0.88, 1.16) |

Sensitivity Model: overweight ($n = 1,122$), 0 = normal weight ($n = 1,207$)

PLAY-ON represents the name of the study where self-reported data were collected in 2007–2008 from a convenience sample of grades 5–8 students attending 30 elementary schools in Ontario, Canada

* $P < 0.05$, ** $P < 0.001$

^a Odds ratios adjusted for all other variables in the table

^b Includes data imputed for respondents with missing body mass index (BMI) data

the targeting of school-based obesity prevention programs and policies, we did not consider examining characteristics of the home environment.

Numerous studies have examined individual-level factors associated with youth overweight. Consistent with this research (Leatherdale and Papadakis 2009; Singh et al. 2010; Seliske et al. 2009), we found that active youths are less likely to be overweight than inactive youths. However, many of the associations between other student characteristics and overweight previously identified in the literature were not significant in this study. For instance, overweight was not associated with time spent in sedentary behaviour or having active friends. Unlike our results, the results of existing research has found an association between overweight and one or more of the student-level characteristics we tested (Singh et al. 2010; Cecil-Karb and Grogan-

Kaylor 2009; Ewing et al. 2006). Considering that this was an elementary school sample and that the analytical focus was geared towards identifying school-level correlates associated with overweight, this may not be surprising.

Previous research on older adolescent populations has also reported problems with large amounts of missing self-reported BMI data (Tiggemann 2006). Consistent with Tiggemann (2006), additional analyses performed with the PLAY-ON data identified an age-related trend where the prevalence of missing BMI data was higher for younger respondents (Arbour-Nicitopoulos et al. 2010). Moreover, considering our sample was composed of even younger respondents than that of Tiggemann (2006), a lack of awareness of one's height or weight among the younger aged respondents in our sample may be underlying this non-response. Exploratory analyses also revealed that

students with missing BMI data in PLAY-ON were more likely to perceive themselves to be overweight or to be low active and highly sedentary (Arbour-Nicitopoulos et al. 2010). When we performed our sensitivity analyses, these assumptions were used to impute missing values among our sample and we found similar results as the results from our primary analyses. Despite such attempts to demonstrate our findings are robust, it is possible that some of the results identified in the present study may be biased (e.g. the lack of associations between-school characteristics or sedentary behaviour and overweight); consequently, the results presented should be interpreted with caution. Strategies to reduce missing data in the self-reporting of height and weight in ways which are sensitive to children need to be developed and evaluated if self-report is used exclusively to monitor and evaluate obesity-related interventions and initiatives.

Limitations

A large amount of BMI data were missing in the host study and previous analyses revealed that there were some differences in the sample characteristics of students with and without BMI data which may bias the results (Arbour-Nicitopoulos et al. 2010). Data were not available to examine energy intake in the present study so our understanding of student-level characteristics associated with obesity may be limited. It was also not possible to examine the impact of specific school-based programs and interventions which may have been in place in the participating schools and their potential interactions with opportunity structures in the built environment. Causal relationships cannot be inferred from these cross-sectional data and since data were collected in a convenience sample the results may not be generalized to the entire population. Although data were based on self-reports, the measures in the PAM have been previously demonstrated to be reliable and valid (Wong et al. 2006), and honest reporting was encouraged by ensuring confidentiality during data collection.

Progress in reducing or limiting the increase in the prevalence of youth overweight will require efforts from many different stakeholders in many different contexts. While school-based interventions alone will not be sufficient to solve the problem, it is unlikely that the current trends can be reversed without more effective partnerships between school- and community-based prevention programming (Story et al. 2009). In this study, a substantial number of youth were considered overweight; despite using self-report height and weight measures and missing data. Moreover, the likelihood of youth in this sample being overweight was associated with both their individual characteristics and the characteristics of the neighbourhood environment surrounding their school. Given the sample

demographics are consistent with other youth populations (Shields 2006; Janssen et al. 2005), these should be meaningful in other contexts. Developing a better understanding of the school- and student-level characteristics associated with overweight among youth is critical for informing intervention programs and policies, and designing school neighbourhoods supporting obesity prevention and reduction among youth populations. It was identified that even though most of the students in this sample are considered a healthy body weight, a substantial number of youth were overweight or obese. Moreover, students in the lower grades of our sample were more likely to be overweight if they attended a school with a larger number of fast-food retailers or grocery stores in the surrounding community environment. Future research should evaluate if the optimal population level impact for school-based obesity prevention programming might be achieved most economically if interventions selectively targeted the schools that are putting students at the greatest risk.

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References

- American Dietetic Association (2006) Position of the American Dietetic Association: individual-, family-, school-, and community-based interventions for pediatric overweight. *J Am Diet Assoc* 106:925–945
- Anderson PM, Butcher KE (2006) Childhood obesity: trends and potential causes. *Future Child* 16:19–45
- Arbour-Nicitopoulos KP, Faulkner GE, Leatherdale ST (2010) Learning from missing data: interpreting missing Body Mass Index (BMI) values in young children. In: 3rd International congress on physical activity and public health, Toronto, ON, Canada, 06 May 2010
- Borradaile KE, Sherman S, Vander Veur SS, McCoy T, Sandoval B, Nachmani J et al (2009) Snacking in children: the role of urban corner stores. *Pediatrics* 124:1293–1298
- Cecil-Karb R, Grogan-Kaylor A (2009) Childhood body mass index in community context: neighborhood safety, television viewing, and growth trajectories of BMI. *Health Soc Work* 34:169–177

- Centers for Disease Control and Prevention (2006) BMI—Body Mass Index: about BMI for children and teens. BMI growth charts for male and female youth. www.cdc.gov/nccdphp/dnpa/BMI/childrens_bmi/about_childrens_bmi.htm
- Colditz G, DeJong W, Hunter D, Trichopoulos D, Willett W (1996) Harvard report on cancer prevention. Volume 1. Causes of human cancer. *Cancer Causes Control* 7:S3–S58
- Davis B, Carpenter C (2009) Proximity of fast-food restaurants to schools and adolescent obesity. *Am J Pub Health* 99:505–510
- ESRI (2002) ArcView GIS 3.3. Redlands, CA
- Evenson KR, Scott MM, Cohen DA, Voorhees CC (2007) Girls' perception of neighborhood factors on physical activity, sedentary behavior, and BMI. *Obesity* 15:430–445
- Ewing R, Borwanson RC, Berrigan D (2006) Relationship between urban sprawl and weight of United States youth. *Am J Prev Med* 31:464–474
- Galvez MP, Hong L, Choi E, Liao L, Godbold J, Brenner B (2009) Childhood obesity and neighborhood food-store availability in an inner-city community. *Acad Pediatr* 9:339–343
- Grafova IB (2008) Overweight children: assessing the contribution of the built environment. *Prev Med* 47:304–308
- Herman KM, Craig CL, Gauvin L, Katzmarzyk PT (2009) Tracking of obesity and physical activity from childhood to adulthood: the Physical Activity Longitudinal Study. *Int J Pediatr Obes* 4:281–288
- Janssen I, Katzmarzyk PT, Boyce WF, Vereecken C, Mulvihill C, Roberts C et al (2005) Comparison of overweight and obesity prevalence in school-aged youth from 34 countries and their relationships with physical activity and dietary patterns. *Obes Rev* 6:123–132
- Kurc A, Leatherdale ST (2009) The effect of social support and school- and community-based sports on youth physical activity. *Can J Pub Health* 100:60–64
- Leatherdale ST, Papadakis S (2009) A multi-level examination of the association between older social models in the school environment and overweight and obesity among younger students. *J Youth Adolesc* Dec 16 [Epub ahead of print]
- Leatherdale ST, Wong SL (2008) Modifiable characteristics associated with sedentary behaviours among youth. *Int J Pediatr Obes* 3:93–101
- Leatherdale ST, Manske S, Wong S, Cameron R (2009) Integrating research, policy and practice in school-based physical activity prevention programming: the School Health Action, Planning and Evaluation System (SHAPES) Physical Activity Module. *Health Promot Pract* 10:254–261
- Leatherdale ST, Manske S, Faulkner G, Arbour-Nicitopoulos K, Bredin C (2010) A multi-level examination of school programs, policies and resources associated with physical activity among elementary school youth in the PLAY-ON study. *Int J Behav Nutr Phys Act* 7:6. doi:10.1186/1479-5868-7-6
- McMurray RG, Ring KB, Treuth MS, Welk GJ, Pate RR, Schmitz KH et al (2004) Comparison of two approaches to structured physical activity surveys for adolescents. *Med Sci Sports Exerc* 36:2135–2143
- Murnaghan DA, Sihvonen M, Leatherdale ST, Kekki P (2007) The relationship between school-based smoking policies and prevention programs on smoking behavior among grade 12 students in Prince Edward Island: a multilevel analysis. *Prev Med* 44:317–322
- O'Malley PM, Johnston LD, Delva J, Bachman JG, Schulenberg JE (2007) Variation in obesity among American secondary school students by school and school characteristics. *Am J Prev Med* 33:S187–S194
- Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM (2006) Prevalence of overweight and obesity in the United States, 1999–2004. *JAMA* 295:1549–1555
- Pouliou T, Elliott SJ (2010) Individual and socio-environmental determinants of overweight and obesity in urban Canada. *Health Place* 16:389–398
- Powell LM, Auld MC, Chaloupka FJ, O'Malley PM, Johnston LD (2007) Associations between access to food stores and adolescent body mass index. *Am J Prev Med* 33:S301–S307
- Rasbash J, Browne W, Healy M, Cameron B, Chalton C (2005) MLwiN version 2.02. Institute of Education, Multilevel Models Project
- Seliske LM, Pickett W, Boyce WF, Janssen I (2009) Association between the food retail environment surrounding schools and overweight in Canadian youth. *Public Health Nutr* 12:1384–1391
- Shields M (2006) Overweight and obesity among children and youth. *Health Rep* 17:27–42
- Singh AS, Paw MJMCA, Brug J, van Mechelen W (2007) Short-term effects of school-based weight gain prevention among adolescents. *Arch Pediatr Adolesc Med* 161:565–571
- Singh GK, Siahpush M, Kogan MD (2010) Rising social inequalities in US childhood obesity, 2003–2007. *Ann Epidemiol* 20:40–52
- Storey ML, Forshee RA, Weaver AR, Sansalone WR (2003) Demographic and lifestyle factors associated with body mass index among children and adolescents. *Int J Food Sci Nutr* 54:491–503
- Story M, Nanney MS, Schwartz MB (2009) Schools and obesity prevention: creating school environments and policies to promote healthy eating and physical activity. *Millbank Q* 87:71–100
- Tiggemann M (2006) Nonreporting of body mass index: a research note on the interpretation of missing data. *Int J Eat Disord* 39:346–349
- Trost SG, Kerr LM, Ward DS, Pate RR (2001) Physical activity and determinants of physical activity in obese and non-obese children. *Int J Obes* 25:822–829
- Veugeliers P, Sithole F, Zhang S, Muhajarine N (2008) Neighbourhood characteristics in relation to diet, physical activity and overweight of Canadian children. *Int J Pediatr Obes* 3:152–159
- Veugliers PJ, Fitzgerald AL (2005) Effectiveness of school programs in preventing childhood obesity: a multilevel comparison. *Am J Pub Health* 95:432–435
- Wong SL, Leatherdale ST, Manske S (2006) Reliability and validity of a school-based physical activity questionnaire. *Med Sci Sports Exerc* 38:1593–1600