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ORIGINAL ARTICLE

Influence of neighbourhood design and access to facilities on overweight among preschool children

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Abstract

Objective. Studies of the role of the built environment in relation to obesity in young children have reported inconsistent results. *Methods*. We explored the association of objective measures of neighbourhood design (dwelling density, land use mix, intersection density, availability of facilities) with the bodyweight status of 501 preschool children (girls = 262; boys = 239) residing in Edmonton, Canada. *Results*. Approximately 21% of the children were classified as overweight or at-risk of being overweight according to the Centers for Disease Control (CDC) growth charts, while 15% of the children were considered overweight or obese according to the International Obesity Task Force (IOTF) criteria. Controlling for measures of physical activity, junk food consumption and neighbourhood-level social class, significant interactions were found between sex of the child and walkability of the neighbourhood (composite index of dwelling density, land use mix, and intersection density) and sex of the child and intersection density regardless of the bodyweight status criteria. The odds of girls being overweight or obese were lower if they lived in walkable neighbourhoods (OR = 0.78, 95%CI, 0.66–0.91 CDC; OR = 0.73, 95%CI, 0.61–0.88 IOTF) with more intersections (OR = 0.57, 95%CI, 0.39–0.86 CDC; OR = 0.48, 95%CI, 0.30–0.76 IOTF). No significant associations were observed for boys. *Conclusion*. Thus, aspects of the built environment may differentially influence the bodyweight status of children depending upon sex.

Key words: *Obesity, environment and public health, geographic information systems, sex-differences, children*

Introduction

Approximately 25% of preschool children in North America are overweight or at-risk of overweight (1–3). In a recent review (4), strong to moderate evidence was found for associations between overweight among young children and maternal pre-pregnancy body size, maternal smoking during pregnancy, children's television/media use, breast-feeding (inverse association), and physical activity (inverse association). However, little is known about the relationship between community design and childhood overweight. This fact is surprising considering that the environment has been implicated as perhaps the most important factor in the weight status of populations (5,6) with physical activity and food intake being the most likely mediators of environmental influences on bodyweight (7). For instance, suburban sprawl and the way neighbourhoods are designed have been linked to physical inactivity and obesity among adults (8–12). In addition, aspects of the built environment (access to facilities, neighbourhood design) are associated with physical activity (13–17), and overweight among adolescents (14).

In three cross-sectional studies conducted exclusively with preschool children, neither parental perceptions of neighbourhood safety (18,19) nor objective measures of neighbourhood crime, access to playgrounds, or exposure to fast food restaurants (20) were associated with overweight. However, a recent study of 7 334 children and youth ranging in age from 3 to 18 years found that objective measures of neighbourhood vegetation and proximity of food retail locations in Marion County, Indiana significantly predicted overweight (21). Also, the socioeconomic status (SES) of neighbourhoods or communities appears to be associated with

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overweight among young children, with those living in lower SES areas being at much higher risk of overweight (22,23). Not surprisingly, recent calls have been made for more research on the possible association between the built environment and obesity among young children (4,24).

A potentially important factor to consider when examining the role of the built environment on overweight among young children is whether gender moderates the influence of environment on bodyweight status. For instance two recent studies with adults found that between area variation in body mass index (BMI) is greater for women than men (25,26). Among children and youth, associations have been reported between aspects of the built environment and physical activity for girls but not boys (16,27). Thus, female residents of neighbourhoods may be more susceptible to environmental determinants of overweight.

The primary purpose of this study was to explore whether objective measures of neighbourhood design and access to facilities were related to the bodyweight status of preschool children. Specifically, we measured the "3Ds of urban form" (28) that influence physical activity: diversity (mixed land use), density (neighbourhood density), and design (street network patterns). Though Frank and colleagues (9,10) have shown these variables to be associated with walking and obesity among adults, and not related to bodyweight among adolescents (16), we speculated that as young children are dependent on their parents for opportunities to be active and interact with their neighbourhood environment that these indicators of walkability may be associated with the bodyweight status of the children. A second purpose was to determine whether gender moderated any associations between measures of neighbourhood design and bodyweight status. Because food intake and physical activity are two of the most likely mediators of environmental influences on bodyweight (7), measures of these two variables were included in all analyses. Finally, because SES is associated with rates of overweight and obesity (22,14,29) and access to facilities (14) among North American youth, all analyses controlled for indicators of neighbourhood-level SES.

Methods

Participants

This article is based on a cross-sectional analysis of pilot data for a longitudinal cohort study on determinants of childhood obesity. The population of interest was children between four and six years of age who attended one of 10 health centres for preschool immunization within the Capital Health region encompassing Edmonton, Canada. These 10 health centres are located across the region and represent areas with diverse socioeconomic and demographic characteristics. Of the 3 429 children approached, 720 were recruited and entered into the study for a recruitment rate of 21%. Complete bodyweight and geographic data were available for 501 children (boys = 239; girls = 262) residing in 171 neighbourhoods. The average age of the sample was 4.95 years (standard deviation, SD = 0.40). Participant characteristics are shown in Table I.

Measures

Demographics. Age and sex were recorded when the child visited the health centre. No information was collected on household income, education, or employment status. Data on neighbourhood-level education, income, and employment status was extracted from the 2001 Census (30). Because the increase in the proportion of women in the workforce has been identified as a potential explanation for why the per capita number of fast food and full-service restaurants are associated with the rise in obesity in the United States (31), the proportion of employed females in the neighbourhood was included as a relevant measure of SES.

Physical activity. For physical activity, the parent/guardian estimated the number of hours per week that their child participated in both structured physical activity (e.g., sport or classes) and play. Specifically, they were asked, "Thinking back over the past couple of weeks, approximately how many hours per week did your child do the following?"

Table I. Characteristics of preschool children by sex.

	Boys[a]	Girls[b]
Age (years)	5.0 ± 0.4	4.9 ± 0.4
Height (cm)	110.7 ± 5.9	110.2 ± 7.9
Weight (kg)	19.7 ± 3.6	19.1 ± 3.4
BMI (kg/m^2)	16.0 ± 2.2	15.7 ± 2.2
Proportion at-risk/overweight (CDC)	22.0	21.0
Proportion overweight/obese (IOTF)	13.0	16.0
Junk food consumption (items/week)	8.9 ± 6.1	8.6 ± 6.6
Proportion physically active (≥10.5 hours/week)	85.0*	77.0

Note. Except for proportion overweight (%) and proportion physically active (%), data are mean value ± standard deviation. CDC = Centres for Disease Control and Prevention growth charts (33); IOTF = International Obesity Task Force cut-off criteria (34).
[a]n = 239. [b]n = 262.
*$p < 0.05$.

Options included "attend regularly scheduled activities or classes (e.g., basketball, swimming, gymnastics, hockey)", "watch TV", "play video and/or computer games (e.g., Nintendo, Game Boy)", or "play actively inside and/or outside". To get an estimate of total physical activity, the number of hours of activity were then aggregated across the two physical activity items (regularly scheduled activities and play). According to recent Canadian guidelines (32), children should be active at least 90 minutes per day, which is equivalent to 10.5 hours per week. Thus, physical activity status was determined by whether the child was physically active 10.5 hours or more per week. No validity or reliability information is available for these questions.

Junk food consumption. The parent/guardian was asked to report on the dietary intake of their child. Specifically, the parent/guardian was asked, "Thinking back over the past couple of weeks, how many servings has your child had of the following foods and beverages? Estimate the number of servings for each food or beverage, either over an average day or over an average week. If your child rarely or never has the food or beverage, write zero per day or per week." The options then consisted of 19 items asking about daily or weekly servings of foods and beverages, such as fruit, vegetables, bread, meat, dairy products, chips, juice, and pop (soft drink). While total caloric intake could not be estimated based upon these items, an index of weekly junk food consumption was created by standardizing and then aggregating across 7 items (chips, French fries, candy, chocolate bars, cookies/cake, ice cream, and pop); a higher score indicated more consumption. No validity or reliability information is available for either this question or index.

Height and weight. Weight was assessed to the nearest 0.1 kg using a calibrated scale. Height was assessed using a stadiometer to the nearest 1.0 mm. Body mass index (BMI) was calculated according to a standard formula (BMI $=$kg/m^2). Both the CDC growth charts (33) and the IOTF cut-off criteria (34) were used to classify the children according to bodyweight status based upon age and sex. Specifically, children were classified as being at-risk of overweight or overweight if their BMI was at the 85 centile or higher according to the CDC growth charts (33) and were classified as being overweight or obese if they were at, or exceeded, the adult equivalent of a BMI of 25 according to the IOTF criteria (34).

Neighbourhood environment characteristics. Measures of neighbourhood design and access to physical activity facilities were created using geographic information systems (GIS). Based upon the 6-digit postal code, Arcview 9.1 (Redlands, CA) was used to determine dwelling density, street connectivity (intersection density), and land use mix within the child's neighbourhood along with the number of physical activity facilities within a 1 500 meter radius of the centroid of the neighbourhood. Dwelling density was calculated as the ratio of the number of dwelling units, as identified in the 2001 Census (30), to the neighbourhood area. Intersection density was calculated as the ratio of the number of true intersections (defined as intersections of three or more streets) to the neighbourhood area. Land use mix was estimated based on the density of facilities belonging to institutional, maintenance, dining (including fast food), and leisure categories (35). These facilities were identified using on-line versions of the Yellow Pages™ and the Alberta Business Directory. Based upon the procedures described by Frank et al. (10), a walkability index was then derived for each neighbourhood by taking the sum of the z-scores for intersection density, dwelling density, and land use mix with intersection density being weighted twice that of dwelling density and land use mix.

Procedures

Parents were approached about their child participating in a study after making an appointment with a local health centre for a preschool immunization visit for their child. Typically, these appointments are scheduled within a period of two to four weeks after the first contact. Once an appointment was made, the parents or guardians of the child were contacted and asked if they would be willing for their child to participate in the study and if they would be willing to complete a brief questionnaire about their child, including demographic information, physical activity behaviour, and dietary intake. If consent was provided, then a questionnaire package was sent by mail to the parents. They were asked to complete the questionnaire and bring it with them when they brought their child to the health centre. If they forgot to bring the questionnaire to the health centre, then they were asked to complete another version while they waited for their child. Recruitment and data collection occurred between 22 March 2004 and 1 October 2004.

As part of the preschool immunization visit in the Capital Health region, the height and weight of children are routinely measured. For the purposes of this study, all weigh scales (Healthometer 592KL) were professionally calibrated and checked to ensure they met CDC standards (36). Professionally inspected vertical stadiometers (Healthometer Height Rod) attached to the scales were utilized to ensure accuracy and reliability of height measurements. When necessary, new equipment was purchased to replace older equipment. Finally, health centre staff received an in-service program on childhood obesity issues, as well as how to accurately collect anthropometric data and counsel families.

Analysis

Before proceeding with our analyses, we first considered whether our data was of a hierarchical nature that required the application of multilevel modelling. First, because the children were recruited through health centres, there was a possibility that health centres would have a contextual effect. That is, the scores for the children would not be independent of one another within the health centres. To address the issue of whether scores may have been nested within health regions, we first conducted chi-square tests for each bodyweight classification. No significant association was found between health centre and bodyweight status for either CDC, χ^2 (9, N = 501) = 12.16, p = 0.20, or IOTF criteria, χ^2 (9, N = 501) = 7.95, p = 0.59. A second consideration was whether neighbourhood would serve as a contextual variable in this dataset. Since the 501 children represented 171 neighbourhoods across the City of Edmonton (M = 2.93 children per neighbourhood), a multilevel analysis was not appropriate. With approximately 3 children per neighbourhood we were well below the recommended rules of thumb of 20 to 30 observations per group (neighbourhood) (37). In fact only 4 (2.3%) of the neighbourhoods had 10 or more children while 35 (20%) had 5 or more children. Thus, we were reasonably confident that we could proceed with our analysis without considering the potential effect of health centres or neighbourhoods in a multilevel model.

In separate logistic regressions, the two different criteria for bodyweight status (CDC, IOTF) were regressed on neighbourhood-level education, proportion of employed women in the neighbourhood, age of the child, sex, physical activity status, junk food consumption, the walkability index, and interaction terms for sex with the walkability index. Any significant interactions were followed up with an inspection of the individual parameter estimates. Neighbourhood-level income was excluded from the analysis because it was highly correlated with education and proportion of employed women in the neighbourhood.

To determine which specific components, if any, of the walkability index were associated with bodyweight status we then conducted a second set of logistic regressions separately for boys and girls. These regressions were similar to the first set except replacing the walkability index with dwelling density, intersection density, and land use mix. A similar analysis was conducted for a number of sport and play facilities within 1 500 meters of the centroid of each child's neighbourhood.

Results

According to the CDC criteria, 21% of the children were classified as at-risk of overweight (12.6%) or overweight (8.7%) while 15% were considered overweight (11%) or obese (4%) using the IOTF criteria (see Table I). No significant sex differences existed in bodyweight status for either the CDC criteria, χ^2 (1, N = 501) = 0.10, p = 0.75, or the IOTF criteria, χ^2 (1, N = 501) = 0.90, p = 0.34. However, the proportion of boys reported to be physically active 10.5 hours or more per week (85%) was significantly higher, χ^2 (1, N = 501) = 5.41, p = 0.02, than that for girls (77%).

In the first set of logistic regressions, significant interactions were found between sex and walkability for both the CDC, χ^2 (2, N = 501) = 12.95, p = 0.002, and IOTF criteria, χ^2 (2, N = 501) = 14.08, p = 0.001. Inspection of the individual parameter estimates revealed that for girls, walkability was negatively associated with CDC bodyweight status (B = −0.26, OR = 0.78, 95%CI, 0.66–0.91). No significant association was observed for boys between walkability and CDC bodyweight, (B = −0.10, OR = 0.90, 95%CI, 0.79–1.03). According to the IOTF criteria, walkability (B = −0.32, OR = 0.73, 95%CI, 0.61–0.88) was a significant predictor of bodyweight status for girls. No significant association was observed for boys between walkability and IOTF bodyweight, (B = −0.10, OR = 0.91, 95%CI, 0.77–1.07). Neither physical activity nor junk food consumption was associated with bodyweight status. Based upon the Nagelkerke R-square statistic, the models accounted for approximately 5% (CDC) and 7% (IOTF) of the variance in bodyweight status.

For the specific components of walkability, significant interactions were found between sex and intersection density for both the CDC, χ^2 (2, N = 501) = 9.01, p = 0.011, and IOTF criteria, χ^2 (2, N = 501) = 11.76, p = 0.003. Inspection of the individual parameter estimates (see Table II) revealed that for girls, intersection density was negatively associated with CDC bodyweight status (B = −0.56, OR = 0.57, 95%CI, 0.39–0.86); indicating that for every unit increase in intersection density, the odds of a girl being at-risk/overweight decreased by a factor of 0.57. No significant association was

Table II. A comparison of predictors of the bodyweight status of preschool children by weight reference classification and sex.

	At-risk of Overweight/Overweight (CDC)		Overweight/Obese (IOTF)	
	Females	Males	Females	Males
	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)
Dwelling density	0.75 (0.48 to 1.15)	0.94 (0.67 to 1.33)	0.71 (0.44 to 1.16)	0.99 (0.65 to 1.48)
Land use mix	0.80 (0.47 to 1.36)	0.87 (0.58 to 1.30)	0.83 (0.47 to 1.45)	1.00 (0.66 to 1.52)
Intersection density	0.63 (0.41 to 0.96)*	0.72 (0.49 to 1.05)	0.46 (0.28 to 0.76)**	0.72 (0.47 to 1.12)
Facility access (1500 m)	1.01 (0.98 to 1.03)	1.01 (0.99 to 1.03)	0.99 (0.97 to 1.02)	1.01 (0.99 to 1.04)

Note. Odds ratios were adjusted for the age of the child, proportion of employed women in the neighbourhood, proportion of people with less than high school education in the neighbourhood, physical activity status, and junk food consumption.
CDC = Centres for Disease Control and Prevention growth charts (33); IOTF = International Obesity Task Force cut-off criteria (34).
*$p < 0.05$.
**$p < 0.01$.

observed for boys between intersection density and CDC bodyweight. According to the IOTF criteria, intersection density ($B = -0.74$, $OR = 0.48$, 95%CI, 0.30–0.76) was a significant predictor of bodyweight status for girls. Thus, for every unit increase in intersection density the odds of a girl being overweight or obese by adult standards decreased by a factor of 0.48. No significant association was observed for boys between intersection density and IOTF bodyweight. Neither physical activity nor junk food consumption was associated with bodyweight status. Finally, no other significant associations were observed for either bodyweight classification and the other neighbourhood environment variables including the number of sport and play facilities.

Discussion

In this study we explored whether aspects of neighbourhood design and access to facilities were associated with risk of overweight among young children. Regardless of the criteria used to classify bodyweight, we found that the walkability of neighbourhoods and intersection density in particular, were associated with the odds of being at-risk/overweight/obese among preschool girls but not boys. The odds of a young girl being at-risk/overweight/obese were 22% to 43% lower if she lived in a walkable neighbourhood with higher intersection density than a girl who did not live in such a neighbourhood. These findings were independent of neighbourhood SES and parental reports of their children's physical activity and junk food consumption. In contrast to other studies conducted exclusively with preschool children (18–20), this is the first study to document associations between objective measures of urban form and risk of overweight among preschool children. The fact that our findings were independent of neighbourhood SES suggests that the social patterning of fat mass (38) may be mediated to some extent by the built environment for females. Meaning that observed associations between socioeconomic status and bodyweight status of children (22,23,39,40) may be partially explained by the built environment.

Our finding that gender did moderate the association between aspects of neighbourhood design and bodyweight status of young children suggests that females may be more susceptible to environmental determinants of obesity. Other research has shown gender differences in relation to the environment for obesity among adults (25) and physical activity among adults (41) and youth (16,17,27,42). In a sample of youth aged 5 to 18 years, intersection density was positively associated with walking for girls (42). However, Norman et al. (16) found intersection density was negatively related to objectively measured physical activity among female adolescents; suggesting that neighbourhoods with few intersections, such as those found in most North American suburbs, are more promotive of physical activity among adolescents. Perhaps young children are more dependent on their parents than adolescents for most of their physical activity and food intake. Thus, neighbourhoods that are more promotive of walking for adults may result in more opportunities for young girls to be physically active while accompanying their parents. Since we controlled for physical activity levels of the children in our regression analyses, it appears that the influence of urban form on bodyweight status is independent of physical activity. However, our measure of physical activity was a subjective estimate of a child's behaviour on the part of a parent and may not be a good measure of total daily energy expenditure. For instance, Hume et al. (27) found associations between perceived environment of neighbourhoods and objectively measured physical activity for girls, but not boys, among a sample of 10-year-old

Australian children. Further research adopting prospective designs using objective measures of environment, energy expenditure, and bodyweight are necessary to determine the role of the built environment on the bodyweight status of young children.

Previous research has shown associations between availability of recreation space or green space and physical activity (13,14,17,42–45) and overweight (14,21) among youth. Boys in particular appear to be more physically active if they have easy access to recreation space (17,45). We measured the number of physical activity facilities, including parks and playgrounds, within 1 500 meters of the centroid of each child's neighbourhood and found no associations with either physical activity or bodyweight status. One possible explanation for the lack of associations is that the City of Edmonton has a very equitable distribution of playgrounds with the lower SES neighbourhoods having the greatest accessibility (46).

Based upon the CDC criteria, our combined rate of 21% of children being at-risk/overweight is slightly lower than a rate of 24% recently reported in a study following a similar protocol in Calgary, Alberta (1). The difference in findings may be due to the fact that the Calgary study was reporting on a surveillance program whereas our participants were being recruited for a longitudinal cohort study. Some parents of obviously overweight or obese children may not have agreed to allow their children to participate for various reasons. Consistent with other research (47–49) we did find a difference in prevalence estimates between the CDC and IOTF criteria with the CDC criteria resulting in higher rates of at-risk/overweight children. However, these differences between the criteria did not appear to influence the outcome of our regression analyses. While the magnitude of the associations between aspects of neighbourhood design (walkability, intersection density) and bodyweight status appeared to be slightly larger for female children when following the IOTF criteria, the overlap in confidence intervals for the odds ratios suggests that these differences are not statistically significant.

This study is not without limitations, including the cross-sectional design, relatively low response rate, use of parental reports of physical activity and dietary intake, and use of unvalidated measures of physical activity and dietary intake. Our recruitment rate of 21% is low and, as discussed previously, may have resulted from the fact that participants were being recruited for a longitudinal cohort study. Thus it is possible that our sample is biased in terms of the proportion of overweight children or the attitudes of the parents. A limitation of particular concern is the fact that household income and education data were not collected. While neighbourhood-level SES data was included in the analysis and may serve as a reasonable indicator of household SES, research has shown that both levels of SES are independently associated with obesity among Canadian adolescents (29). Therefore, some of the observed associations between measures of urban form and overweight in the current study may be explained by household SES. Strengths of the study included the objective measures of height, weight, urban form, and access to facilities.

Future research should consider the role of gender when investigating environmental correlates of overweight and obesity among children. If it is the case that aspects of neighbourhood design differentially influence the bodyweight status of young boys and girls, then implications for interventions and programs become more apparent.

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Author contributions

Joy Edwards and Judy Evans were responsible for the development and management of the study including coordination with the Public Health Centres. Nicoleta Cutumisu carried out the spatial analysis. John Spence conducted the statistical analyses and wrote the final draft. All authors commented on the manuscript.

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