Body Mass Index in Urban Canada: Neighborhood and Metropolitan Area Effects

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Objectives. We investigated the influence of neighborhood and metropolitan area characteristics on body mass index (BMI) in urban Canada in 2001.

Methods. We conducted a multilevel analysis with data collected from a cross-sectional survey of men and women nested in neighborhoods and metropolitan areas in urban Canada during 2001.

Results. After we controlled for individual sociodemographic characteristics and behaviors, the average BMIs of residents of neighborhoods in which a large proportion of individuals had less than a high school education were higher than those BMIs of residents in neighborhoods with small proportions of such individuals ($P<.01$). Living in a neighborhood with a high proportion of recent immigrants was associated with lower BMI for men ($P<.01$), but not for women. Neighborhood dwelling density was not associated with BMI for either gender. Metropolitan sprawl was associated with higher BMI for men ($P=.02$), but the effect was not significant for women ($P=.09$).

Conclusions. BMI is strongly patterned by an individual's social position in urban Canada. A neighborhood's social condition has an incremental influence on the average BMI of its residents. However, BMI is not influenced by dwelling density. Metropolitan sprawl is associated with higher BMI for Canadian men, which supports recent evidence of this same association among American men. Individuals and their environments collectively influence BMI in urban Canada. (*Am J Public Health.* 2007;97:500–508. doi:10.2105/AJPH.2004.060954)

Consistent evidence suggests that the prevalence of obese and overweight people is increasing rapidly around the world in both developing and developed countries, including Canada.[1–6] The prevalence of combined obese and overweight people (body mass index [BMI]$\geq$25 kg/m^2) in Canada increased from 48% to 57% among men and from 30% to 35% among women during the 15 years between 1981 and 1996.[7] The increase was indeed a national phenomenon: the rates increased in each province.[8] The speed of the rise in obesity rates suggests that the root of the obesity pandemic in developed countries is an environment that supports obesity,[9–11] rather than a shift in the genetic composition of the population.

Individual BMI is associated with multiple factors, including genotype, metabolism, energy intake, and level of physical activity. Socioeconomic, cultural, and environmental factors influence health-related behaviors, which in turn influence weight.[2] It is these influences—the interplay between adult BMI, social position, behavior, and environment—that are the principal focus of this paper. We take the approach that BMI is a function of individual characteristics (e.g., age, income level, immigrant status, exercise patterns, diet) along with neighborhood (e.g., neighborhood educational level, density of dwellings) and metropolitan area contexts (e.g., sprawl).

Sobal and Stunkard[12] reviewed 144 studies published between 1933 and 1988 that examined the relation between socioeconomic status (SES) and obesity. The vast majority of these studies found an inverse association between social position and obesity for women, but the findings for men were inconsistent. Studies that followed the 1989 review by Sobal and Stunkard have generally supported their findings,[13–16] but recent American research suggests the disparity in obesity across SES has decreased in the past 30 years.[17]

Many variables act as mediators in the association of social position and obesity, including smoking[18] and psychological stress.[19,20] However, individual factors alone (e.g., social position, health behaviors) cannot explain variations in BMI.[21] Studies that consider the relation between BMI and the environment tend to focus on 2 broad aspects: sociodemographic characteristics of neighborhoods and overall urban form (density, land-use mix, and street connectivity).

Although a large body of literature exists regarding neighborhood health effects,[22–26] researchers have only recently attempted to examine the relation between neighborhood socioeconomic conditions, urban form, and body weight. Ellaway et al.[27] interviewed 691 individuals from 4 socially contrasting neighborhoods in Glasgow, Scotland. They found twice the number of obese individuals in the most economically deprived area of the city compared with individuals from the most affluent area. In a Dutch study,[28] after adjusting for the educational level, age, and gender of neighborhood residents, investigators found that risk of becoming overweight increased with level of neighborhood social deprivation. The authors of the Dutch study suggest that differences in neighborhood resources, such as the availability and price of healthy foods and the presence and quality of sports facilities and parks, may be related to both dietary intake and physical activity levels.

Modern suburban neighborhoods, which are characterized by work, school, and commercial land uses that are not easily accessible on foot or bicycle, likely constrain the amount of time people spend walking or cycling for utilitarian purposes. As a result, levels of physical activity for people who live in sprawling neighborhoods tend to be lower than for those who live in higher density, more compact neighborhoods.[29–34] Frank et al.[35] demonstrated that mean BMI for White men decreased significantly across neighborhoods as land-use mix, density, and street connectivity increased.

METHODS

The data sources for this study were the 2000–2001 Canadian Community Health Survey (CCHS) and the 2001 Canadian Census of Population. The CCHS provides cross-sectional data about health determinants, health status, and use of health care for a large sample of Canadians (N=131 535) (for more details on the CCHS see Beland[36]). For our study, respondents aged 20 to 64 years (excluding pregnant women and individuals who reported height ≥7 ft or <3 ft), who resided in a census metropolitan area (CMA), were included. CMAs are the 27 largest Canadian urban areas.

Outcome Variable

BMI is the standard unit of measure for weight and obesity in populations and is calculated by dividing a person's weight in kilograms by their height in meters squared. BMI was calculated for CCHS respondents according to self-reported height and weight. Self-reporting of height and weight is a limitation of this study, because individuals may over report their height or underreport their weight.[37]

Explanatory Variables

We assumed that BMI is influenced by factors at 3 levels: individual, neighborhood, and metropolitan area. We hypothesized that, at the individual level, demographic characteristics (age, marital status, immigrant status), social position (income, educational attainment), health-related behaviors (smoking, physical activity, and diet), and stress are important predictors of BMI (Table 1).

Neighborhoods were defined as census tract areas (CTAs), geostatistical areas containing about 4000 people. We have demonstrated elsewhere[36] that CTAs are suitable proxies for "natural" neighborhoods in contextual effects studies. We hypothesized that both social and physical characteristics of neighborhoods have an incremental effect on BMI. Social characteristics are defined by the proportion of recent immigrants (≤5 years), the proportion of individuals who have low educational attainment, and the neighborhood median household income. A measure of dwelling density (dwellings per km^2) was a proxy for the "walkability" of a neighborhood (a physical attribute).

We also considered the characteristics of the larger metropolitan areas and tested our hypothesis that living in a sprawling metropolitan area has an incremental effect on BMI. Investigators have used a variety of methods and data sources (including population, land use and transportation data, and remotely sensed images)[38–42] to define, model, and measure sprawl in American cities. Lopez[43] developed a method based on population density and compactness to examine the association between urban sprawl and being overweight among American adults.

The method presented by Lopez[43] was attempted here, although it proved to be ineffective for Canadian metropolitan areas that had several low-density CTAs. Our index (similar to the one presented in Razin and Rosentraub[42]) was composed of 3 equally weighted dimensions of sprawl: proportion of CMA dwellings that are single or detached units, dwelling density, and percentage of CMA population living in the urban core (an urban area around which a CMA is delineated and contains a minimum of 100,000 residents). CMAs were sorted from least to most sprawling for each measure and then assigned a value of 1 to 27. The 3 ranked scores were summed together to produce a cumulative sprawl rank; the lower values reflected less sprawl (Table 2). The validity of the sprawl index is suggested by the low sprawl score for Montreal, an island city in which architectural styles favor multidwelling units. The western Canadian prairie has sprawling cities (e.g., Edmonton, Regina, Saskatoon) because of abundant, relatively inexpensive land that surrounds these areas. Affluence was measured by median CMA household income (Canadian dollars). A dummy variable was added to indicate CMAs in the province of Quebec, because exploratory analyses showed that the BMI profile of these CMAs was systematically lower than the other CMAs.

Statistical Methodology

We developed gender-specific, 3-level models (incorporating normalized sampling weights) of individual BMI that offered simultaneous consideration of i adults nested within j urban neighborhoods, in turn nested within k metropolitan areas. The "null" model (model A), was estimated with no explanatory variables. The null model measures the relative importance of individual, neighborhood, and metropolitan area effects to variation in the outcome. We built models incrementally and first added individual-level covariates (model B), then added neighborhood-level covariates (model C), and finally added the metropolitan-level covariates (model D). ML Win (University of Bristol, Bristol, England) software version 1.10 was used to estimate all of the models.

An intraclass (neighborhood and metropolitan levels) correlation coefficient was used to judge the effect of explanatory variables included in the model.[44] The coefficient is the ratio between the neighborhood-based variations or the metropolitan area–based variation and the total variation. A decline in the intraclass correlation coefficient indicates that differences between metropolitan areas or neighborhoods have been reduced by the inclusion of explanatory variables.

RESULTS

There were 15 686 men and 17 278 women with valid BMI measures and responses to the individual-level explanatory variables in the models (Table 1). Dummy variables for missing information about income and physical activity were created to retain cases (not shown in the results). Men were distributed among 2615 CTAs and women were distributed among 2660 CTAs.

Separate multilevel models were created for men and women because factors associated with BMI tend to differ by gender. Mean BMI for men was 26.1 and for women it was 24.7; the standard deviation of BMI was higher for women (5.1 vs 4.2). Mean BMIs for men and women tended to be lowest in Vancouver and Victoria, British Columbia; Toronto, Ontario; and 4 CMAs in Quebec (Sherbrooke, Chicoutimi, Quebec, and Montreal).

Body Mass Index in Men

The amount of variation in BMI among men that was attributable to neighborhoods

TABLE 1—Self-Reported Sample Characteristics: Canadian Community Health Survey, 2000–2001, and Canadian Census Data, 2001

	Men and Women			Men (n = 15 686)				Women (n = 17 278)			
	Mean	Range	SD	Mean	Range	SD	n (%)	Mean	Range	SD	n (%)
Outcome variable: BMI, kg/m^2				26.10	9.3–75.6	4.21		24.72	10.2–67.8	5.12	
Individual level											
Age, y				40.09	20–64	11.63		41.24	20–64	11.80	
Income adequacy,[a] $											
Lowest income quartile							1 362 (8.68)				2 140 (12.39)
Lower middle income quartile							2 299 (14.66)				3 126 (18.09)
Upper middle income quartile							5 274 (33.62)				5 794 (33.53)
Highest income quartile[b]							5 683 (36.23)				4 936 (28.57)
Missing income							1 068 (6.81)				1 282 (7.42)
Education											
Less than high school diploma							2 233 (14.24)				2 384 (13.80)
High school and some college							2 919 (18.61)				3 590 (20.78)
College degree[b]							10 534 (67.16)				11 304 (65.42)
Marital status											
Married							9 497 (60.54)				10 066 (58.26)
Previously married							1 754 (11.18)				3 143 (18.19)
Never married[b]							4 435 (28.27)				4 069 (23.55)
Smoking											
Current smoker							5 035 (32.1)				4 793 (27.74)
Former smoker							6 295 (40.13)				6 303 (36.48)
Never smoker[b]							4 356 (27.77)				6 182 (35.78)
Work-related physical activity[c]											
Sedentary							3 950 (25.18)				4 659 (26.96)
Stand, walk, lift/carry loads, perform heavy work[b]							10 421 (66.44)				11 984 (69.36)
Leisure physical activity[d]											
Inactive							7 347 (46.84)				9 271 (53.66)
Moderately active							3 514 (22.40)				4 179 (24.19)
Active[b]							3 518 (22.43)				3 201 (18.53)
Nutrition											
< 5 servings of fruits/vegetables per day							11 086 (70.67)				10 004 (57.90)
≥ 5 servings fruits/vegetables per day[b]							4 600 (29.33)				7 274 (42.10)
Self-reported daily stress											
High stress							4 588 (29.25)				5 479 (31.71)
Low or regular stress[b]							11 098 (70.75)				11 799 (68.29)
Immigrant status											
Immigrant ≤ 5 years							611 (3.90)				576 (3.33)
Immigrant > 5 years							2 912 (18.56)				3 131 (18.12)
Nonimmigrant[b]							12 163 (77.54)				13 571 (78.54)
Neighborhood level (n = 4287)											
Recent (≤ 5 years) immigrants, %	4.27	0–45.06	5.39								
Low education, %	24.53	0–66.46	10.63								
Median household income, $	53 683.92	10 032–21 6361	20 593.86								
Dwelling density	1580.84	0.44–30 500.00	2131.88								

Continued

TABLE 1—*Continued*

			Metropolitan area level (n = 27)
Median household income, $	48 267	35 969–62 956	6 819.42
Sprawl[e]	42	3–74	18.48

Source. Adapted from Razin and Rosentraub.[42]
[a]Income adequacy classifies the total household income (Canadian dollars) based on the number of people living in the household into 4 groups: lowest (less than $15 000 for 1 or 2 people, less than $20 000 for 3 or 4 people, less than $30 000 for 5 or more people), lower middle ($15 000–29 999 for 1 or 2 people, $20 000–39 999 for 3 or 4 people, $30 000–59 999 for 5 or more people), upper middle ($30 000–59 999 for 1 or 2 people, $40 000–79 999 for 3 or 4 people, $60 000–79 999 for 5 or more people), and highest ($60 000 or more for 1 or 2 people, $80 000 or more for 3 people or more).
[b]Reference category.
[c]Measure of energy expenditure based on activity level at work.
[d]Measure of energy expenditure based on various types of physical activity, during leisure time only, during the previous 3 months: inactive (< 6.30 kJ/kg/day [< 1.5 kcal/kg/day]), moderately active (6.30–12.56 kJ/kg/day [1.5–2.99 kcal/kg/day]), active (12.57 kJ/kg/day [≥ 3.0 kcal/kg/day]).
[e]Average rank among 3 measures of sprawl (population density, dwelling density, and % of dwelling units that are single or detached).

TABLE 2—Rankings for 27 Canadian Census Metropolitan Areas (CMAs) From Least to Most Sprawling: Canadian Census Data, 2001

Census Metropolitan Area	Cumulative Sprawl Rank[a]	Detached Dwelling Units, %	Rank	Dwelling Density[b]	Rank	% of Population in Core[c]	Rank
Montreal	3	31.71	1	350.20	1	96.66	1
Toronto	9	44.84	5	276.95	2	95.78	2
Vancouver	16	43.19	3	263.58	3	92.09	10
Quebec	19	41.85	2	93.55	10	93.03	7
Kitchener	20	55.51	11	185.35	5	93.49	4
Victoria	21	50.77	9	195.01	4	92.45	8
Hamilton	28	58.96	17	184.49	6	93.42	5
Calgary	37	61.35	19	70.11	15	94.56	3
London	37	55.79	12	74.20	14	89.25	11
Abbotsford	39	56.66	15	81.51	11	87.86	13
Trois-Rivieres	39	47.52	7	67.67	16	85.64	16
Ottawa-Hull	40	45.47	6	78.21	13	79.81	21
Sherbrooke	41	43.25	4	59.82	18	82.80	19
Winnipeg	44	61.74	21	65.03	17	93.36	6
Windsor	45	69.96	25	115.12	8	89.01	12
St. John's	46	56.39	14	80.57	12	81.32	20
Chicoutimi-Jonquiere	50	50.10	8	35.47	20	79.77	22
St Catharines-Niagara	51	69.51	24	107.27	9	83.56	18
Edmonton	52	59.37	18	37.85	19	86.80	15
Oshawa	53	65.49	23	115.37	7	79.24	23
Halifax	56	52.45	10	26.28	22	76.90	24
Regina	58	70.32	26	22.49	23	92.44	9
Saskatoon	60	61.70	20	17.13	26	87.11	14
Kingston	60	56.36	13	30.59	21	73.66	26
Thunder Bay	68	71.07	27	19.44	24	84.61	17
Saint John	68	58.45	16	14.36	27	73.98	25
Greater Sudbury	74	64.36	22	17.86	25	66.76	27

Note. Cumulative rank range: 3–81.
[a]For single-unit dwellings.
[b]Dwellings per km^2.
[c]Defined as an urban area around which a CMA is delineated and contains a minimum of 100 000 residents.

and metropolitan areas was 4.39% and 1.35%, respectively (Table 3, model A). These values tended to decline but remain significant across the models as covariates were added, which indicates that most, but not all, of the variation in BMI between neighborhoods and metropolitan areas can be attributed to the composition of the population living in those areas. The intercept in the null model (Table 3, model A) provides the estimated average BMI for men aged 20–64 years in urban Canada (26.265), which is classified as overweight.

There were significant associations between individual demographic characteristics, social position, health behaviors, stress, and BMI in men (Table 3, model B). Recent immigration had a large effect on BMI (−1.787, $P<.01$) and the effect declined for individuals who had been in Canada longer than 5 years (−0.847, $P<.01$). BMI was significantly higher for older men than for younger men and for married and previously married men than for unmarried men. The relation of BMI in men with income was characterized by a gradient of lower BMI across decreasing income categories. A poor diet and physical inactivity were associated with higher BMI values. Men who reported high stress also had significantly higher BMIs than those who reported little or no daily stress (0.287, $P<.01$). Smokers (−0.545, $P<.01$) had significantly lower BMIs than nonsmokers. The −2 log likelihood measure indicates the steady improvement in models A through D with additional explanatory variables at the neighborhood and metropolitan levels.

TABLE 3—Body Mass Index Model Results for Men (n = 15 686): Canadian Community Health Survey, 2000–2001, and Canadian Census Data, 2001

	Model A			Model B			Model C			Model D		
	Estimate (β)	SE	P	Estimate	SE	P	Estimate	SE	P	Estimate	SE	P
Intercept	26.265	0.107	<.01	25.500	0.163	<.01	25.503	0.161	<.01	25.578	0.151	<.01
Individual level												
Age, y				0.043	0.003	<.01	0.043	0.003	<.01	0.043	0.003	<.01
Lowest income quartile[a]				−0.557	0.135	<.01	−0.581	0.137	<.01	−0.583	0.137	<.01
Lower middle income quartile[b]				−0.316	0.106	<.01	−0.340	0.108	<.01	−0.338	0.108	<.01
Upper middle income quartile[c]				−0.080	0.080	<.01	−0.099	0.081	<.01	−0.096	0.081	<.01
Income missing				−0.476	0.134	<.01	−0.504	0.135	<.01	−0.505	0.134	<.01
Less than high school diploma				0.276	0.102	<.01	0.202	0.103	.03	0.203	0.103	.03
High school diploma or some college				0.231	0.086	<.01	0.193	0.086	.03	0.194	0.086	.03
Married				0.693	0.087	<.01	0.649	0.087	<.01	0.652	0.087	<.01
Previously married				0.390	0.140	<.01	0.359	0.140	<.01	0.359	0.140	<.01
Daily smoker				−0.545	0.087	<.01	−0.563	0.087	<.01	−0.566	0.087	<.01
Former smoker				0.219	0.082	<.01	0.216	0.082	<.01	0.215	0.082	<.01
Daily activity: sedentary				0.256	0.078	<.01	0.291	0.079	<.01	0.294	0.079	<.01
Leisure activity: moderate[d]				0.496	0.099	<.01	0.486	0.098	<.01	0.490	0.098	<.01
Leisure activity: inactive[e]				0.526	0.087	<.01	0.514	0.087	<.01	0.520	0.087	<.01
Fruit/vegetable consumption				0.190	0.073	0.01	0.182	0.073	.01	0.177	0.073	.02
High self-reported daily stress				0.287	0.073	<.01	0.288	0.073	<.01	0.293	0.073	<.01
Recent immigrant (≤5 y)				−1.787	0.169	<.01	−0.164	0.173	<.01	−1.641	0.173	<.01
Immigrant (≥5 y)				−0.847	0.089	<.01	−0.805	0.091	<.01	−0.804	0.091	<.01
Neighborhood level												
% recent immigrant (≤5 y)							−0.022	0.009	.02	−0.024	0.009	.01
% without high school diploma							0.021	0.005	<.01	0.021	0.005	<.01
Median household income							0.003	0.003	.36	0.002	0.003	.46
Dwelling density							−0.029	0.023	.20	−0.025	0.023	.26
Metropolitan area level												
Median household income										0.019	0.013	.15
Sprawl										0.010	0.004	.02
Quebec										−0.439	0.264	.10
Variance components												
City	0.241	0.083	<.01	0.226	0.077	<.01	0.189	0.067	<.01	0.055	0.028	.04
Neighborhood	0.783	0.101	<.01	0.606	0.090	<.01	0.577	0.089	<.01	0.579	0.089	<.01
Individual	16.811	0.204	<.01	15.917	0.193	<.01	15.903	0.193	<.01	15.903	0.193	<.01
Intracity correlation coefficient, %	1.35			1.35			1.13			0.33		
Intraneighborhood correlation coefficient, %	4.39			3.62			3.46			3.50		
Overall: −2 loglikelihood	88678.27			87852.38			87794.76			87772.52		

[a]Defined as less than Canadian $15 000 for 1 or 2 people, less than $20 000 for 3 or 4 people, less than $30 000 for 5 or more people.
[b]Defined as Canadian $15 000–29 999 for 1 or 2 people, $20 000–39 999 for 3 or 4 people, $30 000–59 999 for 5 or more people.
[c]Defined as Canadian $30 000–59 999 for 1 or 2 people, $40 000–79 999 for 3 or 4 people, $60 000–79 999 for 5 or more people.
[d]Defined as 6.30–12.56 kJ/kg/day (1.5–2.99 kcal/kg/day).
[e]Defined as 6.30 kJ/kg/day (<1.5 kcal/kg/day).

Two neighborhood characteristics were statistically significant, and after including individual-level covariates, approximately 3.5% of neighborhood-level variation remained (Table 3, model C). Men who resided in neighborhoods with a high proportion of recent immigrants had lower BMI scores (−0.022, *P*=.02) than men who lived in other neighborhoods. Men in neighborhoods with a high proportion of individuals of low educational attainment had incrementally higher BMI scores (0.021, *P*<.01). Dwelling density and median household income of the neighborhood were not associated with BMI in men.

Living in a sprawling metropolitan area was associated with higher BMI scores in men, even after neighborhood and individual factors were accounted for (0.010, $P=.02$) (Table 3, model D). CMA median household income was not associated with higher BMI scores for men, nor was there an incremental effect of Quebec residence for men.

Body Mass Index in Women

The amount of variation in BMI among women attributable to neighborhoods and metropolitan areas was 4.44% and 1.42%, respectively (Table 4, model A). These values tended to decline but remain significant across the models as covariates were added. The intercept in the null model (Table 4, model A) provides the estimated average BMI for women aged 20–64 years in urban Canada (24.946), which is classified as normal weight.

We found significant associations between individual demographic characteristics, social position, health behaviors, stress, and BMI in women, but many of these followed a different pattern from men (Table 4, model B). We found an association between advanced age and increased BMI for both men and women, although the magnitude of this association was larger for women than for men (0.079, $P<.01$ vs 0.043, $P<.01$) (Tables 3 and 4, model B). Being a recent immigrant had a large effect on BMI among women (–1.764, $P<.01$), but the effect declined for immigrants who had been in Canada longer than 5 years (–0.803, $P<.01$). BMI was significantly higher (1.080, $P<.01$) for women who did not complete high school when compared with women with at least some college education. The magnitude of the educational effect was far greater for women than for men. The BMI of married women was not significantly different from single women, although the BMI for previously married women was significantly lower (–0.180, $P=.02$) than for single women. The relation between BMI in women and income was roughly characterized by a reverse gradient; higher BMI is seen in lower levels of income adequacy. When we looked at behavioral influences, physical inactivity was associated with higher BMI values in women, and the magnitude of that association was much higher for women than for men (1.153, $P<.01$ vs 0.526, $P<.01$). Some patterns, however, were similar for men and women. Women who reported high stress also had significantly higher BMIs than women who reported low or no daily stress (0.318, $P<.01$). Also like men, female smokers (–0.491, $P<.01$) had significantly lower BMIs than nonsmokers. The –2 log likelihood measure indicates the steady improvement in models A through D with additional explanatory variables at the neighborhood and metropolitan levels.

The only variable that contributed explanatory significance to the 2.91% variation in the neighborhood-level model for women was low educational attainment (Table 3, model C). Women who reside in neighborhoods where there is a high proportion of individuals who have low educational attainment had incrementally higher BMI scores (0.042, $P<.01$) than women who live in neighborhoods populated with more highly educated individuals. Dwelling density and median household income of the neighborhood were not associated with BMI for women or for men.

Metropolitan affluence was not associated with BMI for Canadian women and the association with sprawl was in the expected direction but showed marginal significance (Table 4, model D). There remained, however, a large association between BMI in women and residing in a metropolitan area in Quebec (–0.972, $P=.01$), even after accounting for neighborhood and individual factors. The variation at the CMA level was statistically significant but small at 0.62%.

DISCUSSION

BMI was strongly affected by individual social position in urban Canada, although the magnitude of the effect differed for men and women. Neighborhood and metropolitan area environments registered incremental effects on BMI for both genders. There was a strong association between immigrant status and BMI for both men and women, and this association attenuated with length of time in Canada. These findings are reminiscent of other studies that showed that immigrant populations begin to take on the health profile of their host societies.[45] Although we have not studied the variation in immigrant BMI by country of origin, BMI has been shown to increase in Canadian adults with time since immigration, regardless of self-ascribed ethnicity.[46]

The magnitude of the association between low educational attainment and BMI for women suggests that strategies to keep girls in high school could have dramatic effects on the distribution of BMI for women. The hypothetical BMI increase for women who do not graduate from high school relative to women who complete college studies was nearly a full BMI unit. The relation between income and BMI was shown to be different for men and women. It has been argued that in the United Kingdom obesity is a marker for social position,[47] and obesity is associated with being lower down the social ladder; however, this is not the case for Canadian men. This gender contingency in the BMI social gradient is likely rooted in complex social factors including societal roles and norms as well as access to resources that support healthy body weights, such as time for activity.

We found small incremental effects of neighborhood- and metropolitan-level environments on the BMI of men and women in urban Canada. These effects related primarily to 2 neighborhood characteristics (low education levels and the presence of immigrants [men only]) and 2 metropolitan area characteristics (sprawl [BMI in men] and residence in a Quebec CMA [BMI in women]). The fact that low education levels were associated with incrementally higher BMI values for both men and women may be related to norms and practices around diet and exercise in those neighborhoods, but might also be related to issues of neighborhood safety, availability and quality of recreational opportunities, or access to healthy food. One might surmise from the neighborhood-level findings that recent immigrants bring with them customs and norms regarding diet or physical activity that become part of local practice and influence behaviors beyond the immigrant community. This is a contextual healthy-immigrant effect that would be worthy of more study on a local scale.

Our study provides some support for the findings of recent American research[40,43,48] (although we used a more extensive set of control variables) that suggests that sprawling cities and their characteristic low-density

TABLE 4—Body Mass Index Model Results for Women (n = 17 278): Canadian Community Health Survey, 2000–2001, and Canadian Census Data, 2001

	Model A			Model B			Model C			Model D		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
Intercept	24.946	0.130	<.01	23.302	0.208	<.01	23.438	0.205	<.01	23.586	0.185	<.01
Individual level												
Age, y				0.079	0.004	<.01	0.081	0.004	<.01	0.081	0.004	<.01
Lowest income quartile[a]				0.913	0.145	<.01	0.796	0.147	<.01	0.798	0.147	<.01
Lower middle income quartile[b]				0.932	0.119	<.01	0.824	0.120	<.01	0.828	0.120	<.01
Upper middle income quartile[c]				0.594	0.095	<.01	0.521	0.096	<.01	0.525	0.096	<.01
Income missing				−0.035	0.149	<.01	−0.107	0.149	<.01	−0.106	0.149	<.01
Less than high school diploma				1.080	0.117	<.01	0.936	0.118	<.01	0.938	0.118	<.01
High school diploma or some college				0.445	0.093	<.01	0.378	0.093	<.01	0.376	0.093	<.01
Married				0.139	0.101	.02	0.079	0.102	.03	0.077	0.102	.03
Previously married				−0.180	0.139	.02	−0.230	0.139	.03	−0.233	0.139	.03
Daily smoker				−0.491	0.098	<.01	−0.503	0.098	<.01	−0.502	0.098	<.01
Former smoker				0.465	0.089	<.01	0.496	0.089	<.01	0.498	0.089	<.01
Daily activity: sedentary				0.606	0.086	<.01	0.626	0.085	<.01	0.628	0.085	<.01
Leisure activity: moderate[d]				0.659	0.115	<.01	0.651	0.115	<.01	0.655	0.115	<.01
Leisure activity: inactive[e]				1.153	0.103	<.01	1.114	0.103	<.01	1.120	0.103	<.01
Fruit/vegetable consumption				0.121	0.077	.11	0.101	0.077	.19	0.095	0.077	.21
High self-reported daily stress				0.318	0.081	<.01	0.320	0.080	<.01	0.324	0.080	<.01
Recent immigrant (≤ 5 y)				−1.764	0.208	<.01	−1.704	0.211	<.01	−1.708	0.211	<.01
Immigrant (≥ 5 y)				−0.803	0.104	<.01	−0.821	0.105	<.01	−0.825	0.105	<.01
Neighborhood level												
% Recent immigrant (≤ 5 y)							0.007	0.011	.52	0.005	0.011	.63
% without high school diploma							0.042	0.006	<.01	0.041	0.006	<.01
Median household income							0.004	0.004	.23	0.004	0.004	.34
Dwelling density							−0.038	0.026	.15	−0.037	0.026	.15
Metropolitan area level												
Median household income										0.017	0.018	.36
Sprawl										0.010	0.006	.09
Quebec										−0.972	0.369	.01
Variance components												
City	0.363	0.122	<.01	0.483	0.152	<.01	0.427	0.137	<.01	0.145	0.057	.01
Neighborhood	1.138	0.136	<.01	0.804	0.117	<.01	0.683	0.112	<.01	0.678	0.112	<.01
Individual	24.121	0.278	<.01	22.388	0.257	<.01	22.386	0.257	<.01	22.392	0.257	<.01
Intracity correlation coefficient, %	1.42			2.04			1.82			0.62		
Intraneighborhood correlation coefficient, %	4.44			3.40			2.91			2.92		
Overall: −2 loglikelihood	104 632.70			103 388.10			103 284.30			103 269.70		

[a]Defined as less than Canadian $15 000 for 1 or 2 people, less than $20 000 for 3 or 4 people, less than $30 000 for 5 or more people.
[b]Defined as Canadian $15 000–29 999 for 1 or 2 people, $20 000–39 999 for 3 or 4 people, $30 000–59 999 for 5 or more people.
[c]Defined as Canadian $30 000–59 999 for 1 or 2 people, $40 000–79 999 for 3 or 4 people, $60 000–79 999 for 5 or more people.
[d]Defined as 6.30–12.56 kJ/kg/day (1.5–2.99 kcal/kg/day).
[e]Defined as 6.30 kJ/kg/day (< 1.5 kcal/kg/day).

suburbs—and concomitant dependence upon the automobile for transportation—produce heavier and less healthy populations. Most of the research in this area has focused on American urban environments, and other studies[49] have shown that Canadian urban environments have historically been more protective of population health than their American counterparts. The fact that the association with sprawl also appears to hold in Canada (at least for men) suggests that health and urban sustainability issues cross international boundaries. Although the average man in urban Canada already has a BMI score in the overweight range (approximately 26), an inactive, married man under high stress who lives in a sprawling metropolis has a hypothetical BMI over 27.

Quebec is a Canadian province with a predominantly French-speaking population. Women who live in Quebec CMAs have significantly lower BMIs than do women who live in other CMAs, which suggests that there is a true environmental effect that may represent unmeasured cultural norms or genetic predisposition factors related to body mass. We also tested for the presence of other regional effects (data not shown) but found none. This suggests that differences in average BMI in women between metropolitan areas outside of Quebec are largely attributable to differences in population composition.

A constellation of individual, neighborhood, and metropolitan area factors is associated with BMI in urban Canada. Although the overwhelming amount of variation in BMI occurred at the individual level for both men and women, we found small incremental effects of neighborhood and metropolitan area environments. These environments probably set the stage for many of the individual characteristics and behaviors, so that the neighborhood and metropolitan area effects revealed here are likely underestimated. Rose[50] has argued that small changes that influence the distribution of risk factors across populations have the best potential to improve the health of entire populations. Our results suggest that Canadian urban environments play a small but significant role in shaping the distribution of BMI. They also provide support for altering the contexts in which health improvement behavior occurs and for informing urban sustainability and design policy with human health research. ■

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Contributors

N. Ross originated the idea for the study and led all aspects of the work including data analysis and writing. S. Tremblay, S. Khan, and D. Crouse performed analyses and assisted with writing. M. Tremblay and J-M. Berthelot provided conceptual and methodological expertise and assisted with writing.

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