ORIGINAL ARTICLE

Prevalence of obesity and elevated body mass index along a progression of rurality: A cross-sectional study – The Canadian Longitudinal Study on Aging

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Abstract

Introduction: Obesity is an important public health concern, and large studies of rural–urban differences in prevalence of obesity are lacking. Our purpose is to compare body mass index (BMI) and obesity in Canada using an expanded definition of rurality.

Methods: A cross-sectional analysis of self-reported BMI across diverse communities of Canadians aged 45–85 years was conducted using data from the Canadian Longitudinal Study on Aging (CLSA), a national sample representative of community-dwelling residents. Rurality was identified in the CLSA based on residential postal codes, which were divided into 4 categories: urban, peri-urban, mixed and rural. Logistic regression models were constructed to calculate adjusted odds ratios (aORs) with 95% confidence intervals (95% CIs) between obesity (BMI ≥30 kg/m^2 from self-reported weight and height) and rurality, adjusting for age, sex, province, marital status, number of residents in household and household income.

Results: Twenty-one thousand one hundred and twenty-six Canadian residents aged 45–85 years, surveyed during 2010–2015, were included. 26.8% were obese. Obesity was less prevalent amongst urban (25.2%) than rural (30.3%, $P < 0.0001$), mixed (28.7%, $P < 0.0001$) or peri-urban communities (28.1%, $P < 0.0001$). When compared to urban areas, the aOR (95% CI) for obesity was 1.09 (1.00–1.20) in rural regions and 1.20 (1.08–1.35) in peri-urban settings. In areas of mixed urban and rural residence, the aOR was 1.12 (0.99–1.27).

Conclusion: One in four Canadian adults were obese. Living in a non-urban setting is an independent risk factor for obesity. Rural–urban health disparities could underlie rural–urban differences, but further research is needed.

Keywords: Body mass index, Canadian Longitudinal Study on Aging, obesity, rural

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Résumé

Introduction: L'obésité est un important problème de santé publique et des études de grande envergure sur les différences de prévalence de l'obésité entre les régions rurales et urbaines font défaut. Notre objectif est de comparer l'indice de masse corporelle (IMC) et l'obésité au Canada en utilisant une définition élargie de la ruralité.

Méthodes: Une analyse transversale de l'IMC autodéclaré dans diverses communautés de Canadiens âgés de 45 à 85 ans a été réalisée à l'aide des données de l'Étude longitudinale canadienne sur le vieillissement (ELCV); un échantillon national représentatif des résidents vivant en communauté. Dans l'ELCV, la ruralité a été identifiée à partir des codes postaux résidentiels, qui ont été divisés en 4 catégories: urbain, périurbain, mixte et rural. Des modèles de régression logistique ont été construits pour calculer les rapports de cotes ajustés (RCa) avec des intervalles de confiance à 95% (95% IC) entre l'obésité (IMC ≥30 kg/m^2 à partir du poids et de la taille autodéclarés) et la ruralité, en tenant compte de l'âge, du sexe, de la province, de l'état civil, du nombre de résidents dans le ménage et du revenu du ménage.

Résultats: 21 126 résidents canadiens âgés de 45 à 85 ans, interrogés au cours de la période 2010-2015, ont été inclus. 26,8% étaient obèses. L'obésité était moins répandue dans les communautés urbaines (25,2%) que rurales (30,3%, $P < 0,0001$), mixtes (28,7%, $P < 0,0001$) ou périurbaines (28,1%, $P < 0,0001$). Par rapport aux zones urbaines, le RCa (95% IC) pour l'obésité était de 1,09 (1,00, 1,20) dans les régions rurales, et de 1,20 (1,08, 1,35) dans les milieux périurbains. Dans les zones de résidence mixte urbaine et rurale, le RCa était de 1,12 (0,99, 1,27).

Conclusion: Un adulte canadien sur quatre était obèse. Le fait de vivre dans un milieu non urbain est un facteur de risque indépendant d'obésité. Les disparités en matière de santé entre les régions rurales et urbaines pourraient être à l'origine de ces différences, mais des recherches supplémentaires sont nécessaires.

Mots-clés: Rural, Obésité, Indice de masse corporelle, ELCV

INTRODUCTION

There are many discrepancies in health status between urban and rural residents.[1-4] Some studies show that rural communities have higher rates of comorbidities and mortality.[1] Rural areas have lower availability and accessibility of healthcare services.[2,3] Overall health behaviours are different, with higher rates of smoking and sedentary activity found amongst residents in rural areas.[1] Socioeconomic factors also affect rural residents, as lower income, lower levels of educational attainment and higher unemployment rates are found amongst some rural areas.[1,2] However, there is also significant heterogeneity in rural health research, which is partly due to variations in methodology, setting and the population.

Many challenges exist in comparing rural–urban health status. First, studies vary in how 'rural' and 'urban' are defined.[5] Second, many socioeconomic discrepancies exist across countries, making rural–urban comparisons difficult across societies. Third, rural areas and urban areas are heterogeneous in terms of health status and access to health services. Examining rurality using expanded definitions or categories rather than a strict 'urban–rural' binary categorisation may lessen, but not eliminate this difficulty.[6] Furthermore, many studies focused their analyses in small geographic regions, and there are relatively few representative epidemiological studies including both large urban and rural populations. Therefore, large representative studies of rurality are important to continuously evaluate the presence of health discrepancies. It is important to continuously update findings, as socioeconomic factors and health services change continuously over time.

Obesity is a prevalent risk factor associated with an increase in morbidity and mortality.[7,8] Obesity is also associated with a diverse set of health complications, including cardiovascular disease, non-alcoholic fatty liver disease, osteoarthritis and various solid organ malignancies.[7-9] Body mass index (BMI), a metric of weight (in kilogram) divided by height (in metres squared), is commonly used to define underweight (BMI <18.5 kg/m^2), overweight (BMI 25–29 kg/m^2) and obesity (BMI ≥30 kg/m^2).[10,11] Obesity is associated with a higher all-cause mortality, with higher risks found amongst higher classes of obesity (i.e. higher BMI).[10]

The prevalence and percentage of the population with self-reported obesity are

increasing in Canada.[7] Canada has the fourth highest prevalence of obesity amongst the Organisation for Economic Co-operation and Development countries.[7] Direct and indirect costs of obesity are increasing, and obesity was estimated to cost Canadians $4.6 billion in the year 2008 alone.[7] Weight and obesity have been identified as a priority health concern amongst rural communities.[2] Over the last 30 years, BMI is rising faster in rural settings compared to urban areas in many countries.[12] In countries with emerging economies, rural areas contribute more to rising BMI than urban settings.[12] Obesity is a major public health concern and is associated with socioeconomic inequalities.[4,8,13] Therefore, it is important to understand how the social determinants of health and rurality relate to the prevalence of obesity.[4,7-9]

We conducted a study comparing BMI and the presence of obesity using an expanded definition of rurality. To address many of the previous limitations of urban–rural health studies, we used a large, nationally representative, population-based sample that includes a diverse range of rural and urban communities to address the following two objectives.

1. We examined obesity and mean BMI (using self-reported weight and height) along a progression of rurality (urban, mixed, peri-urban and rural areas)
2. We determined predictors of obesity and BMI in Canada.

METHODS

Study design, population and data sources

We used a cross-sectional design to investigate the association between rurality and BMI. Data from the Canadian Longitudinal Study on Aging (CLSA) were used for this study. The CLSA is a large, multi-faceted, prospective cohort study of community-dwelling Canadian residents aged 45–85 years at the time of recruitment between 2010 and 2015.[14-17] The sampling frame is intended to be as representative of the general population as far as possible. CLSA participants were first recruited from Statistics Canada's Canadian Community Health Survey version 4.2 on Healthy Aging.[18] CLSA then supplemented their initial cohort with a nationally representative sample using provincial healthcare registration databases and random digit dialling to obtain data through telephone interviews.[14-17] This general cohort, termed the CLSA 'tracking cohort', consisted of 21,241 study participants. For this study, we used data gathered from the initial recruitment and baseline interview of the CLSA tracking cohort. The CLSA is ongoing and will follow all participants aged ≥45 years over the next two decades.

Inclusion criteria for the CLSA tracking cohort included: community dwelling adults aged 45–85 years at the time of recruitment, understood English and/or French and resided within a Canadian province. Individuals with cognitive impairment at baseline, resided on a First Nations reserve, who were full-time members of the Canadian Armed Forces or who were not permanent Canadian residents or citizens were excluded. Patients who reported being pregnant, did not know whether they were pregnant or who declined to report their pregnancy status were excluded from our regression analyses. All participants in the CLSA provided informed consent.

Outcomes

BMI was calculated from self-reported weight and height data obtained through computer-assisted telephone interviews.[14,19] Participants were asked 'how tall you are you without shoes on?' for height and 'how much do you weigh? (specified afterwards if the reported weight was in pounds or kilograms)' for weight.[19] Self-reported height was rounded up to the nearest inch when recorded, and weight was recorded exactly as reported.[19] We then converted the data from the CLSA telephone survey to metric units and calculated self-reported BMI.

To ensure reproducibility of our results, we used two different outcome metrics. We classified our outcomes as: (1) a dichotomous variable for the presence of obesity (based on self-reported BMI ≥30 kg/m^2) versus no obesity (BMI <30 kg/m^2) or (2) BMI as a continuous variable. We defined obesity and weight classes based on BMI on the same scale used by the World Health Organization.[11]

Independent study variables of interest

Area of residence, or rurality, was classified based on CLSA and the Canadian Census definitions. We classified the nature of rural–urban communities into four categories, ranging from most rural to most urban: 'rural' (rural), 'mixed' (postal code link to dissemination area), 'peri-urban' (urban fringe, urban population outside census metropolitan areas and census agglomerations and secondary core) and 'urban' (urban core).

Confounding variables included were as follows: biological sex, age (at the time of recruitment), province of residence, education status, marital status, number of other household residents and household income. These variables were all self-reported. The variables were included in our model because sex, age and socioeconomic factors (e.g. education, marital status, income and household living arrangements) were associated with obesity.[4,13,20] These definitions and methods were consistent with our analyses of other outcomes within this data set.[21-23]

Statistical analysis

Bivariate and multivariate analyses were performed. Demographics and socioeconomic variables were compared between areas of residence with either Chi-squared tests or analysis of variance where appropriate. Inflation weights were used when mean BMI was calculated and when BMI was categorised. These weights were provided and calculated by the CLSA to create prevalence estimates that represent the Canadian population.[24] Adjusted odds ratios with 95% confidence intervals (95% CIs) were calculated using multivariate logistic regression with the presence of obesity (BMI ≥30 vs. <30 kg/m^2) as the outcome variable. To ensure the robustness of our results, multivariate linear regression was performed to investigate associations with increased BMI as a continuous outcome variable. Following CLSA protocol, inflation weights were used to portray descriptive statistics (as these weights were designed to be more representative of the general Canadian population) and analytic weights were used for all regression models (as analytic weights were better suited to evaluate the relationship between variables in regression models).[24] We used inflation and analytic weights included in the Baseline Tracking (TRM) Dataset version 3.6. The following regression models were constructed: Model 1 – socioeconomic variables were not included, Model 2 – socioeconomic variables except household income were included and Model 3 – all socioeconomic variables, including household income, were included. Age, sex and province of residence were included as confounder variables in all three adjusted models. Analyses for interactions between variables of interest and rural residence were assessed. Statistical analyses were performed using the software SAS (SAS Analytics in Cary, North Carolina, United States of America).

Ethics approval

The study adhered to the Declaration of Helsinki and these analyses were approved by the University of Manitoba Bannatyne Campus Research Ethics Board.

RESULTS

Table 1 shows the definition of rurality that we used in this study. A total of 21,241 Canadian community-dwelling residents between the ages of 45 and 85 were identified by the CLSA tracking cohort [Table 2]. Only a very small portion (n = 115, 0.5%) of individuals were excluded due to either pregnancy or insufficient data to calculate BMI. After excluding these 115 individuals, a total of 4681 (22.2%) rural, 2624 (12.4%) peri-urban, 2116 (10.0%) mixed and 11,705 (55.4%) urban residents were included in our study.

Over a quarter of Canadians were obese as calculated from self-reported height and weight, and obesity was less common in urban areas. Obesity was present amongst 30.3% of rural, 28.7% of mixed, 28.1% of peri-urban and 25.2% of urban residents (P < 0.0001). The mean self-reported BMIs in our weighted sample were as follows: rural 28.2 kg/m^2, mixed 28.0 kg/m^2, peri-urban 27.8 kg/m^2 and urban 27.4 kg/m^2 (P < 0.0001 for comparisons across geographic areas). Levels of education, household income, marital status and number of household residents [Table 2] differed between urban, peri-urban, mixed and rural communities (P < 0.0001).

Rurality was found to be independently associated with obesity [Table 3]. Higher odds of

Table 1: Definition of rurality adapted from the Canadian Longitudinal Study on Aging survey.

Definition for Analyses	Definition in CLSA	Sample Size	Definition	Examples
Rural	Rural	4707	Area that remains after the delineation of urban areas that have been delineated using current census population data. This includes rural areas inside and outside CMA or CA.	Rossland, BC Edson, AB Lac La Biche, AB Perdue, SK, Humboldt, SK Minnedosa, MB King, ON Princeville, QC Yarmouth, NS Portugal Cove, NL
Mixed	Postal code link to dissemination area	2125	If a postal code covers a large area and it is a mixture of urban and rural area.	The postal code covers rural and non-rural settings
Peri-urban	Urban fringe	445	Small urban areas within a CMA or CA that are not contiguous with the urban core of the CMA or CA.	Whiterock, BC Leduc, AB Cochrane, AB Warman, SK Halton Hills, ON Mercier, QC
Peri-urban	Urban population centre outside CMA and CA	1888	Built up areas that are not contiguous within or contiguous with the urban core of the CMA or CA.	
Peri-urban	Secondary core	304	Population centre within a CMA that has at least 10,000 persons and was the core of a CA that was merged with an adjacent CMA.	
Urban	Urban core	11772	Urban area around which a CMA or a CA is delineated. The urban core must have a population (based on the previous census) of at least 50,000 persons in the case of a CMA, or at least 10,000 persons in the case of a CA.	Kamloops, BC Calgary, AB Medicine Hat, AB Saskatoon, SK Winnipeg, MB Sault Ste. Marie, ON Timmins, ON Val-d'Or, QC Halifax, NS Charlottetown, PEI St. John's, NL

Peri-urban: Includes urban fringe, urban population centre outside CMA and CA, and secondary core. CLSA: Canadian Longitudinal Study on Aging, CMA: Census metropolitan areas, CA: Census agglomerations.

obesity were seen amongst rural and peri-urban residents compared to urban residents, even after adjusting for sociodemographic and socioeconomic variables. Residents of mixed districts were also at higher odds of obesity compared to urban residents in unadjusted and most adjusted models; however, after household income was incorporated into our multivariate logistic regression model, the association became non-significant.

Using linear regression, urban residents had a lower average BMI than rural, peri-urban and mixed communities [Table 4]. Although these associations decreased in magnitude when sociodemographic and socioeconomic variables were adjusted for, a statistically significant positive correlation between rurality and BMI remained [Table 4].

In model checking, we noted statistically significant interactions on the outcome of obesity for a rural residence and age and rural residence and sex. However, the effect size was small and of borderline significance. The interaction terms did not alter the main effect associations that we observed. We therefore presented the regression models without interaction terms.

DISCUSSION

There was a modest, but statistically significant, independent association between urban residence and lower odds of obesity (based on self-reported height and weight) amongst community-dwelling Canadians aged 45–85 years. Even after age, sex, province of residence, education, marital status, number of household residents and household income were adjusted for, both lower odds of obesity and lower mean BMI were witnessed

Table 2: Demographic and socioeconomic characteristics of a nationally representative sample of community-dwelling Canadians as stratified by rurality*

	n (%) of participants					
	Total Sample	Urban	Peri-urban	Mixed	Rural	*P*
Total Sample	21241	11772	2637	2125	4707	
Body Mass Index (kg/m^2)						<0.0001
Underweight: <18.5	186 (0.8)	119 (0.8)	17 (0.7)	11 (0.8)	39 (0.8)	
Normal: 18.5-24.99	6910 (32.7)	4073 (35.1)	779 (29.9)	610 (27.8)	1448 (28.6)	
Overweight: 25.0-29.99	8689 (39.1)	4750 (38.2)	1095 (40.7)	887 (42.4)	1957 (39.8)	
Obesity Class I: 30.0-34.99	3662 (18.0)	1882 (17.3)	506 (20.0)	411 (18.8)	863 (18.8)	
Obesity Class II: 35.0-39.99	1114 (5.8)	581 (5.0)	143 (5.0)	139 (7.3)	251 (8.2)	
Obesity Class III: ≥ 40.0	565 (3.0)	300 (2.9)	84 (3.0)	58 (2.6)	123 (3.3)	
Pregnant or At Least 1 Required Question Not Answered	115 (0.7)	67 (0.8)	13 (0.6)	9 (0.3)	26 (0.5)	
Sex						0.0874
Female	10835 (51.8)	6023 (51.4)	1360 (52.3)	1105 (53.1)	2347 (52.5)	
Male	10406 (48.2)	5749 (48.6)	1277 (47.7)	1020 (46.9)	2360 (47.5)	
Age Group						<0.0001
44-54	5832 (38.1)	3165 (38.1)	719 (37.0)	615 (40.0)	1333 (37.9)	
55-64	6564 (31.4)	3550 (30.5)	870 (35.1)	659 (31.5)	1485 (32.0)	
65-74	4634 (19.0)	2557 (18.9)	517 (16.7)	465 (18.1)	1095 (20.6)	
75-89	4211 (11.5)	2500 (12.4)	531 (11.2)	386 (10.4)	794 (9.5)	
Education						<0.0001
Less than Secondary School Graduation	1986 (20.3)	860 (17.5)	292 (21.4)	262 (28.7)	572 (25.3)	
Secondary School Graduation	2882 (14.6)	1453 (13.9)	384 (15.1)	316 (13.9)	729 (16.3)	
Some Post-Secondary Education	1623 (8.5)	847 (8.4)	237 (10.2)	178 (8.6)	361 (7.9)	
Post-Secondary Degree or Diploma	14667 (56.2)	8559 (59.8)	1714 (53.0)	1365 (48.7)	3029 (50.0)	
Don't Know or Choose Not to Answer Question	83 (0.4)	53 (0.5)	10 (0.4)	4 (0.1)	16 (0.5)	
Marital Status						N/A†
Single, never married or never lived with a partner	1698 (7.8)	1063 (9.1)	170 (5.6)	121 (4.4)	344 (5.9)	
Married or Living with a Partner in a Common-Law Relationship	14601 (75.0)	7639 (71.2)	1878 (78.8)	1588 (81.7)	3496 (81.7)	
Widowed	2361 (7.3)	1399 (7.9)	298 (6.9)	218 (7.3)	446 (5.9)	
Divorced	1995 (7.4)	1323 (9.1)	212 (6.0)	145 (4.8)	315 (4.2)	
Separated	580 (2.5)	345 (2.6)	77 (2.7)	53 (1.8)	105 (2.2)	
Don't Know or Choose Not to Answer Question	6 (0.0)	3 (0.0)	2 (0.0)	0 (0.0)	1 (0.0)	
Number of Individuals in Household						<0.0001
Living alone	4925 (83.8)	3025 (81.5)	594 (84.9)	432 (86.1)	874 (88.9)	
Not Living Alone	16316 (16.2)	8747 (18.5)	2043 (15.1)	1693 (13.9)	3833 (11.1)	
Household income						<0.0001
<$20,000	1347 (6.4)	709 (6.6)	179 (6.0)	139 (5.6)	320 (6.2)	
$20,000 to $50,000	5849 (25.3)	2922 (23.1)	793 (26.9)	666 (28.8)	1468 (29.7)	
$50,000 to $100,000	7220 (33.6)	3950 (32.9)	880 (33.6)	728 (35.7)	1662 (35.0)	
$100,000 to $150,000	3215 (16.6)	1899 (16.9)	396 (16.7)	282 (14.2)	638 (16.1)	
>$150,000	2240 (12.4)	1472 (14.3)	232 (11.4)	190 (10.3)	346 (8.4)	
Don't Know or Choose Not to Answer Question	1370 (5.7)	820 (6.2)	157 (5.3)	120 (5.4)	273 (4.8)	
Self-Reported Income Adequacy						<0.0001
Totally Inadequate	167 (0.9)	101 (1.0)	19 (1.0)	19 (1.0)	28 (0.7)	
Not Very Well	324 (1.7)	177 (2.0)	46 (1.3)	39 (1.9)	62 (1.2)	
With Some Difficulty	1450 (7.2)	748 (6.6)	197 (8.4)	158 (9.6)	347 (7.7)	
Adequately	7337 (35.7)	3866 (34.3)	954 (36.9)	766 (35.9)	1751 (38.8)	
Very Well	9593 (43.1)	5583 (44.9)	1123 (41.8)	895 (38.1)	1992 (40.4)	
Null (Individuals who did NOT complete maintaining contact questionnaire)	2190 (10.6)	1197 (10.4)	276 (10.0)	230 (12.7)	487 (10.7)	
Don't Know or Choose Not to Answer Question	180 (0.8)	100 (0.9)	22 (0.5)	18 (0.8)	40 (0.5)	

*Proportions were calculated using inflation weights as per CLSA protocol in order to be more representative of the Canadian population. Comparisons and *P* values were calculated using Chi-squared tests using analytic weights. †*P*-value cannot be calculated; one cell has a frequency of zero, thus Chi-squared test cannot be performed. BMI: Body mass index, CLSA: Canadian Longitudinal Study on Aging, N/A: Not available

Table 3: Logistic regression analysis examining the relationship between obesity (BMI ≥30) and rurality*

Variable	aOR (95%CI) for Obesity (BMI<30 vs. ≥ 30 kg/m²).			Reference Category
	Model 1†	Model 2‡	Model 3§	
Rurality				
Rural	1.18 (1.08-1.28)	1.14 (1.04-1.25)	1.09 (1.00-1.20)	Urban
Mixed	1.21 (1.08-1.37)	1.18 (1.04-1.33)	1.12 (0.99-1.27)	
Peri-urban	1.27 (1.14-1.41)	1.23 (1.10-1.37)	1.20 (1.08-1.35)	
Age	0.99 (0.99-0.99)	0.99 (0.98-0.99)	0.98 (0.98-0.98)	Continuous
Sex	1.01 (0.94-1.08)	0.99 (0.92-1.06)	0.98 (0.91-1.06)	Male
Education				
Less than secondary school graduation		1.68 (1.49-1.89)	1.52 (1.34-1.73)	Post-Secondary Degree or Diploma
Secondary school graduation		1.54 (1.39-1.71)	1.46 (1.32-1.63)	
Some post-secondary education		1.54 (1.35-1.76)	1.49 (1.30-1.71)	
Marital Status				
Single, never married or never lived with a partner		1.23 (0.95-1.57)	1.14 (0.88-1.49)	Separated
Married/Living with a partner in a common-law relationship		0.89 (0.70-1.12)	0.94 (0.73-1.20)	
Widowed		1.04 (0.81-1.34)	1.08 (0.83-1.41)	
Divorced		1.00 (0.78-1.28)	0.96 (0.74-1.24)	
Number of Individuals in Household				
Living alone		0.92 (0.65-1.29)	0.81 (0.57-1.15)	5 or More Additional People
1 Additional Person		1.00 (0.73-1.38)	0.91 (0.65-1.26)	
2 Additional People		1.03 (0.74-1.43)	0.96 (0.68-1.34)	
3 Additional People		0.91 (0.65-1.27)	0.84 (0.59-1.19)	
4 Additional People		1.11 (0.76-1.61)	1.04 (0.71-1.53)	
Household income				
<$20,000			1.69 (1.37-2.08)	>$150,000
$20,000 to $50,000			1.79 (1.54-2.09)	
$50,000 to $100,000			1.42 (1.23-1.64)	
$100,000 to $150,000			1.38 (1.19-1.61)	

* In accordance to the Canadian Longitudinal Study on Aging protocol, we used analytic weights and all adjusted models included province of residence (results not shown). †Adjusted for age, sex, and province of residence. ‡Adjusted for age, sex, education, marital status, number of individuals in household, and province of residence. §Adjusted for age, sex, education, marital status, number of individuals in household, household income and province of residence. aOR: Adjusted odds ratio, CI: Confidence interval, BMI: Body mass index, CLSA: Canadian Longitudinal Study on Aging

in urban settings compared to rural, peri-urban and mixed communities. The magnitude of associations decreased with adjustment of some socioeconomic factors, suggesting that income, education, living arrangement and marital status may have explained some (but not all) of the urban–rural differences in BMI and obesity.

Other Canadian studies also reported a lower prevalence of obesity and lower BMI within urban settings. A recently published study by Forbes *et al*. found similar results within Atlantic Canada in a slightly younger population.[25] Their study included available data collected during 2009 to 2015 from 17,054 of 31,173 possible participants. Study participants were aged 35 to 69 and resided within Canada's four Atlantic provinces. Forbes *et al*. found that urban residents had modestly lower BMIs than rural residents (mean BMIs were 28.1 in urban vs. 28.5 kg/m^2 in rural areas, $P < 0.001$). Forbes *et al*. found that mean BMIs were lower amongst urban residents than rural residents, even after age, sex, ethnicity, education and health behaviours, such as smoking and alcohol use, were adjusted for using multiple linear regression. Another study by Hajizadeh *et al*. found that obesity (based on adjusted self-reported BMI ≥30 kg/m^2) was more prevalent amongst rural areas of Canada between the fiscal years of 2000–2009.[13] Even when demographic factors, health behaviours (e.g. diet, exercise and smoking) and a variety of socioeconomic variables were accounted for, rurality remained a modest and independent risk factor for obesity.

A lower prevalence of obesity in urban settings could have several explanations. A study in the United States found that urban residents had increased leisure-time physical activity, lower levels of sedentary behaviour, more fruit

Table 4: Linear regression analysis examining the relationship between BMI and rurality*

Variable	β-coefficient for Increase in BMI with 95% Confidence Interval			Reference Category
	Model 1†	Model 2‡	Model 3§	
Intercept	28.51 (28.01 to 29.01)	28.69 (27.67 to 29.72)	28.64 (27.55 to 29.73)	
Rurality				
Rural	0.46 (0.26 to 0.66)	0.40 (0.20 to 0.61)	0.32 (0.11 to 0.53)	Urban
Mixed	0.59 (0.30 to 0.87)	0.51 (0.23 to 0.80)	0.40 (0.10 to 0.69)	
Peri-urban	0.74 (0.48 to 0.99)	0.66 (0.41 to 0.92)	0.62 (0.36 to 0.88)	
Age	-0.03 (-0.03 to -0.02)	-0.04 (-0.05 to -0.03)	-0.05 (-0.06 to -0.04)	Continuous
Sex	-0.57 (-0.73 to -0.41)	-0.65 (-0.81 to -0.49)	-0.67 (-0.84 to -0.51)	Male
Education				
Less than secondary school graduation		1.46 (1.13 to 1.78)	1.20 (0.85 to 1.54)	Post-Secondary Degree or Diploma
Secondary school graduation		1.01 (0.76 to 1.25)	0.89 (0.63 to 1.15)	
Some post-secondary education		0.79 (0.48 to 1.10)	0.71 (0.39 to 1.03)	
Marital Status				
Single, never married or never lived with a partner		0.68 (0.06 to 1.30)	0.65 (-0.02 to 1.32)	Separated
Married/Living with a partner in a common-law relationship		-0.07 (-0.62 to 0.48)	0.14 (-0.46 to 0.73)	
Widowed		0.43 (-0.17 to 1.02)	0.63 (-0.01 to 1.28)	
Divorced		0.39 (-0.20 to 0.99)	0.36 (-0.29 to 1.00)	
Number of Individuals in Household				
Living alone		-0.01 (-0.83 to 0.81)	-0.28 (-1.14 to 0.58)	5 or More Additional People
1 Additional Person		0.14 (-0.61 to 0.90)	-0.07 (-0.85 to 0.72)	
2 Additional People		0.36 (-0.41 to 1.13)	0.22 (-0.58 to 1.02)	
3 Additional People		-0.17 (-0.95 to 0.61)	-0.30 (-1.11 to 0.51)	
4 Additional People		0.26 (-0.60 to 1.13)	0.12 (-0.78 to 1.01)	
Household income				
<$20,000			1.12 (0.62 to 1.62)	>$150,000
$20,000 to $50,000			1.43 (1.11 to 1.75)	
$50,000 to $100,000			0.81 (0.54 to 1.07)	
$100,000 to $150,000			0.70 (0.41 to 0.98)	

* In accordance to the Canadian Longitudinal Study on Aging protocol, we used analytic weights and all adjusted models included province of residence (results not shown). †Adjusted for age, sex, and province of residence. ‡Adjusted for age, sex, education, marital status, number of individuals in household, and province of residence. §Adjusted for age, sex, education, marital status, number of individuals in household, household income and province of residence. CLSA: Canadian Longitudinal Study on Aging, CI: Confidence interval, BMI: Body mass index.

consumption and less consumption of sweetened beverages compared to rural residents.[26] These health behaviours might be due to differences in infrastructure or geography, as rural residents might have more limited access to nutritious foods or have to rely more heavily on vehicles for transportation rather than walking or biking. Our study was not able to account for these variables, and therefore, it is unknown how much these health behaviours may have contributed to the differences seen. Mental health may also impact health behaviours and obesity. Future Canadian studies on a change in BMI and rurality should include health behaviours, mental health and psychiatric comorbidities when examining BMI and rurality. Future studies that examine urban–rural differences in health more fully are important as the risk factors and socioeconomics effects may change differentially between urban and rural regions over time.

Limitations

Our study had strengths and limitations. We used a large and nationally representative sample that was inclusive of multiple rural and urban regions. We used an expanded definition of urbanicity and rurality, rather than a strict urban–

rural dichotomy, which accounted for some of the heterogeneity between rural communities. We were able to adjust for socioeconomic variables, such as income and household living arrangements, which is not always possible when conducting research using large population-based datasets (e.g. hospital administrative data or physician claims databases). Regarding study limitations, obesity was defined solely based on a single BMI cut-off of 30 kg/m^2, and we were unable to account for other metrics of obesity (such as waist circumference). Other nuanced factors that were limited by this definition, such as body composition (e.g. extensive muscle mass) or ethnicity, may also affect BMI interpretation in select subpopulations. Second, we used self-reported measurements of weight and height, which have inaccuracies. A Canadian study found that individuals tend to overestimate height and underestimate weight, especially amongst overweight and obese individuals.[27] This suggests that Canadians would likely have even higher BMIs than our reported findings. However, it is not clear how this misclassification is related to rural residence. Third, this cross-sectional study was only able to capture a single moment in time. Many variables are dynamic in nature, including weight, health behaviours, socioeconomic circumstance and area of residence. Future studies would benefit from examining changes in BMI over time. Fourth, the clinical interpretation of BMI amongst older adults differs from that of younger adults, especially amongst the older adult population. Other competing risks of mortality and disabilities can contribute to an individual's overall health and frailty. Fifth, the CLSA does not collect data on some important subgroups who reside in Canada, such as those residing on First Nation reserves, active armed forces personnel, non-permanent residents or recent immigrants. We therefore caution generalising results to these individuals or communities. Further studies that explore specific Canadian subgroup populations that the CLSA is unable to capture would be beneficial. Sixth, minor rank-order differences in BMI or obesity were observed between the three rural settings when our three models were directly compared. This might have been due to the adjustment of confounders. However, in all cases, obesity had the lowest prevalence in urban settings. Finally, while we indeed found differences in BMI and in obesity rates between settings, the implications regarding the magnitude of these differences for clinical and policy decisions are not clear.

CONCLUSION

Our study demonstrated that a substantial proportion of Canada's population is obese. BMIs were modestly lower in urban settings than rural, peri-urban and mixed communities. Although absolute differences in prevalence of obesity or mean BMI appeared small, individually, the effects could be magnified on a population scale. Furthermore, significant differences were seen even after adjusting for age, sex, province of residence and socioeconomic factors, which suggest the independent effects of rurality. Early interventions are needed to address the underlying social determinants that contribute to obesity. Health systems need to prepare in advance for an increasing burden of obesity-related complications. Increasing accessibility and access to healthcare, public health and social resources (e.g. parks, physical activity programmes and availability of nutritious foods) are needed. Longitudinal research studies of rural–urban differences in obesity-related interventions will be important to help guide policy and management. These studies and interventions should consider a diverse spectrum of communities.

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REFERENCES

1. Kondro W. Health of rural Canadians lags behind urban counterparts. CMAJ 2006;175:1195.
2. Bolin JN, Bellamy GR, Ferdinand AO, Vuong AM, Kash BA, Schulze A, *et al*. Rural healthy people 2020: New decade, same challenges. J Rural Health 2015;31:326-33.

3. Wilson CR, Rourke J, Oandasan IF, Bosco C. Progress made on access to rural healthcare in Canada. Can J Rural Med 2020;25:14-9.
4. Okobi OE, Ajayi OO, Okobi TJ, Anaya IC, Fasehun OO, Diala CS, *et al*. The burden of obesity in the rural adult population of America. Cureus 2021;13:e15770.
5. Cyril S, Oldroyd JC, Renzaho A. Urbanisation, urbanicity, and health: A systematic review of the reliability and validity of urbanicity scales. BMC Public Health 2013;13:513.
6. Sibley LM, Weiner JP. An evaluation of access to health care services along the rural-urban continuum in Canada. BMC Health Serv Res 2011;11:20.
7. Government of Canada, Public Health Agency of Canada, Canadian Institute for Health Information. Obesity in Canada; 2011.
8. Twells L, Janssen I, Kuk J. Canadian Adult Obesity Clinical Practice Guidelines: Epidemiology of Adult Obesity; 2020. Available from: https://obesitycanada.ca/guidelines/epidemiology. [Last updated on 2020 Aug 04].
9. Wharton S, Lau DC, Vallis M, Sharma AM, Biertho L, Campbell-Scherer D, *et al*. Obesity in adults: A clinical practice guideline. CMAJ 2020;192:E875-91.
10. Global BMI Mortality Collaboration; Di Angelantonio E, Bhupathiraju ShN, Wormser D, Gao P, Kaptoge S, *et al*. Body-mass index and all-cause mortality: Individual-participant-data meta-analysis of 239 prospective studies in four continents. Lancet 2016;388:776-86.
11. World Health Organization. Body Mass Index – BMI. Available from: https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi. [Last accessed on 2021 Aug 02].
12. NCD Risk Factor Collaboration (NCD-RisC). Rising rural body-mass index is the main driver of the global obesity epidemic in adults. Nature 2019;569:260-4.
13. Hajizadeh M, Campbell MK, Sarma S. Socioeconomic inequalities in adult obesity risk in Canada: Trends and decomposition analyses. Eur J Health Econ 2014;15:203-21.
14. Raina P, Wolfson C, Kirkland S. Canadian Longitudinal Study on Aging (CLSA) Protocol; 2008. Available from: https://clsa-elcv.ca/doc/511. [Last accessed on 2021 Jan 07].
15. Raina PS, Wolfson C, Kirkland SA, Griffith LE, Oremus M, Patterson C, *et al*. The Canadian longitudinal study on aging (CLSA). Can J Aging 2009;28:221-9.
16. Kirkland SA, Griffith LE, Menec V, Wister A, Payette H, Wolfson C, *et al*. Mining a unique Canadian resource: The Canadian longitudinal study on aging. Can J Aging 2015;34:366-77.
17. Raina P, Wolfson C, Kirkland S, Griffith LE, Balion C, Cossette B, *et al*. Cohort Profile: The Canadian Longitudinal Study on Aging (CLSA). Int J Epidemiol 2019;48:1752-3j.
18. Statistics Canada. Canadian Community Health Survey (CCHS): Annual Component, 2009-2010; Common Content; Derived Variable (DV) Specification. Statistics Canada; 2009.
19. Canadian Longitudinal Study on Aging. 60-min Questionnaire (Tracking Main Wave) version 4.0. 2018. Available from: https://clsa-elcv.ca/doc/446. [Last accessed on 2021 Jan 07].
20. Ohlsson B, Manjer J. Sociodemographic and lifestyle factors in relation to overweight defined by BMI and "Normal-Weight Obesity". J Obes 2020;2020:2070297.
21. Clark K, John PS, Menec V, Cloutier D, Newall N, O'Connell M, *et al*. Healthcare utilisation among Canadian adults in rural and Urban Areas - The Canadian longitudinal study on aging. Can J Rural Med 2021;26:69-79.
22. John PS, Menec V, Tate R, Newall N, O'Connell M, Cloutier D. Functional status in rural and urban adults: The Canadian longitudinal study on aging. J Rural Health 2021; April 22. [doi: 10.1111/jrh. 12578].
23. St John PD, Menec V, Tate R, Newall N, Cloutier D, O'Connell ME. Life satisfaction in adults in rural and urban regions of Canada - The Canadian Longitudinal Study on Aging. Rural Remote Health 2021;21:6631.
24. Canadian Longitudinal Study on Aging. CLSA Technical Document. 2020. Available from: https://www.clsa-elcv.ca/doc/3965. [Last accessed on 2021 Jan 7].
25. Forbes CC, Yu ZM, Cui Y, DeClercq V, Grandy SA, Parker L, *et al*. Rural-Urban disparities in total physical activity, body composition, and related health indicators: An Atlantic PATH study. J Rural Health 2020;36:111-9.
26. Trivedi T, Liu J, Probst J, Merchant A, Jhones S, Martin AB. Obesity and obesity-related behaviours among rural and urban adults in the USA. Rural Remote Health 2015;15:3267.
27. Gorber SC, Shields M, Tremblay MS, McDowell I. The feasibility of establishing correction factors to adjust self-reported estimates of obesity. Health Rep 2008;19:71-82.