The Geography of Overweight in Quebec: Analyzing and Visualizing Spatial Inequalities Using Second-level Residuals

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ABSTRACT

Objective: To discuss critically the contribution of using second-level residuals from multilevel analyses to further the understanding of how place relates to health and to visualize areas, in the province of Quebec (Canada), with above- and below-average levels of overweight.

Methods: Data on 20,449 individuals are from the Canadian Community Health Survey (CCHS Cycle 2.1) and were linked to 51 spatial units. Area-level residuals were computed from a multilevel analysis examining individual and area characteristics associated with the risk of overweight. Mapping the area-level residuals indicates geographic areas where the risk of overweight is higher or lower compared to the provincial adjusted prevalence.

Results: Controlling for socio-economic conditions and lifestyle, distinct spatial patterns of overweight were observed, indicating that the processes linking place to health may differ between men and women and between regional contexts. In some regions, the probability of overweight differed by 23% for men and 38% for women living in privileged conditions in comparison to the province's adjusted prevalence of overweight.

Conclusions: Analyzing and visualizing area-level residuals provides multi-scaled information that could enhance the understanding of the geographic distribution of overweight and has the potential to support more integrated and locally relevant interventions.

Key words: Overweight; obesity; Québec; medical geography; multilevel analysis; population health

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

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During the last decade, there has been a strong research interest in the influence of local context on health, and on overweight and obesity more specifically.¹⁻⁶ Because health inequalities are never fully clarified by ordinary (single-level) statistical models, and part of these inequalities might be explained by the specific context in which one lives,^{7,8} multilevel models are increasingly used to investigate the social determinants of health.⁹⁻¹¹ These models allow for the assessment of variation in health across small areas as a function of both composition (characteristics of the individuals) and context (characteristics of the group) of these areas. Consideration of second-level residuals obtained from multilevel models is particularly interesting because it allows for the identification of 'outliers',¹²⁻¹⁵ i.e., areas with better/worse than expected health outcomes. When individual and area-level variables do not entirely explain the spatial distribution of a health phenomenon, this unexplained variation is not necessarily due to similar spatial processes across space. Rather, it might suggest that specific areas are significantly different from others. Although second-level residual analysis has the potential to contribute to our understanding of spatial inequalities in health, very few studies have employed this method.¹²⁻¹⁵

In a previous multilevel study, we explored the geography of overweight in the province of Quebec, Canada.¹⁶ Findings showed a complex geography, suggesting important differences in the socio-economic and environmental determinants of overweight, especially between men and women and between rural and urban areas.

Using and extending these results, the purpose of this paper is to statistically describe the regional variation in overweight and to geographically visualize areas in the province of Quebec with

above- and below-average levels of overweight. We critically discuss how the analysis of second-level residuals can enhance the understanding of the spatial distribution of health outcomes and its role in formulating hypotheses about the pathways linking place to health and the relevance of such analysis for public health, public policies and interventions.

METHOD

A full description of methods and analyses are presented in our earlier paper,¹⁶ but are summarized here. Data on socio-economic characteristics and health-related behaviours of a sample of 20,449 adults are from the Canadian Community Health Survey Cycle 2.1 (CCHS 2.1, 2003). Respondents also reported on their height and weight, from which their Body Mass Index (BMI) was computed; overweight was defined as a BMI ≥ 25 . To investigate the geography of overweight, 51 spatial units were purposely created by grouping dissemination areas according to area deprivation, rurality and urban sprawl which are contextual factors

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Conflict of Interest: None to declare.

Table 1. Results of Unadjusted and Adjusted Multilevel Models: Association between Overweight and Individual, Demographic, Socio-economic, and Lifestyle Characteristics, As Well As Area-level Characteristics

Demographic and Socio-economic Characteristics	Men		Women	
	Unadjusted Model	Adjusted Model OR 95% CI	Unadjusted Model	Adjusted Model OR 95% CI
Age (years)				
18-24		1.00		1.00
25-44		2.48 1.99-3.10*		2.12 1.63-2.76*
45-64		2.74 2.03-3.71*		3.28 2.45-4.38*
65+		2.14 1.66-2.75*		2.85 2.02-4.03*
Marital status				
Single		1.00		1.00
Previously married		1.13 0.89-1.42		0.95 0.76-1.20
Union		1.50 1.23-1.83*		1.03 0.87-1.22
Disposable income				
High income		1.00		1.00
Low income		1.05 0.89-1.24		1.30 1.09-1.54*
Missing income		1.06 0.83-1.37		1.06 0.89-1.25
Education level				
University		1.00		1.00
College or high school		1.43 1.23-1.66*		1.54 1.19-1.99*
Less than high school		1.54 1.22-1.95*		2.39 1.91-2.98*
Lifestyle				
Fruits or vegetables				
Eat less than 5/day		1.00		1.00
Eat 5 or more/day		0.79 0.68-0.91*		1.07 0.94-1.21
Smoking status				
Current smoker		1.00		1.00
Former smoker		1.75 1.48-2.06*		1.29 1.06-1.56*
Never-smoker		1.62 1.22-2.16*		1.32 1.00-1.74*
Leisure physical activity level				
Active		1.00		1.00
Moderately active		1.15 1.00-1.32		1.14 0.96-1.35
Somewhat active		0.99 0.77-1.29		1.48 1.23-1.78*
Sedentary		1.01 0.85-1.19		1.61 1.35-1.92*
Occupational physical activity				
Physically difficult		1.00		1.00
Usually standing		0.86 0.70-1.07		1.03 0.77-1.37
Usually seated		1.08 0.83-1.40		1.17 0.89-1.55
Area-level Characteristics				
Rural		1.17 1.02-1.33*		0.96 0.83-1.10
Materially deprived		0.86 0.74-1.01		1.16 0.98-1.37
Socially deprived		0.93 0.80-1.08		0.93 0.77-1.12
Variance Estimation				
Coefficient (std error)	0.041 (0.013)*	0.036 (0.008)*	0.088 (0.037)*	0.05 (0.018)*
Intraclass correlation coefficient	1.23%	1.08%	2.61%	1.59%
Overall predicted probability	55.75%	20.26%	42.80%	8.50%

* Significant at $p < 0.05$ All of the table except "Overall predicted probability" was originally published in: Lebel A, Pampalon R, Thériault M, Hamel D. The geography of overweight in Québec: A multilevel perspective. *Can J Public Health* 2009;100(1):18-23. Reproduced with permission.

reported to be associated with overweight^{6,17-19} (for further details on the design of the spatial units, please refer to this methodological supplement: ftp://ftp.crad.ulaval.ca/Pub/crad/Lebel_2008_Area.pdf).

Statistical analysis

Data were analyzed using multilevel models, as they allow for the assessment of variation in overweight across areas as a function of both composition and context of these areas and further account for the non-independence of the within-group observations and quantify the magnitude of variation between and within groups.

First, multilevel logistic regression models, estimated separately for men and women, are used to obtain estimates of between-area variance in overweight (null or unadjusted model) and to measure individual and area-level factors associated with increased likelihood of reporting overweight (adjusted model). The adjusted model contains information on socio-economic status and health-related behaviours at the individual level and information on rurality and deprivation (social and material) at the area level. The partition of the variation in overweight between individuals and between areas is measured using the intra-class correlation coefficient (ICC), which indicates the relative importance of the contextual effect,²⁰ and the overall predicted probability (OPP), which provides an estimate of the average probability of observing a specific health indicator across all area units.²¹

Then, second-level residuals are computed for the unadjusted and adjusted models to give, respectively, the unadjusted estimated area-level proportion of overweight and the estimated area-level proportion of overweight for the reference person in the fully adjusted models. The reference person is aged between 18 and 24, single, with a high income and a university diploma, eats less than five fruits or vegetables per day, smokes, is physically active, and lives in an urban area that is materially and socially privileged. These individual characteristics were chosen based on our previous models in which they were significantly associated with lower odds of overweight.¹⁶ For each of the 51 areas, the difference in risk of overweight compared to the average risk was estimated by dividing the area's probability on the adjusted OPP.

Finally, results are presented cartographically, allowing visualization of the spatial distribution of the unexplained variance in overweight across areas.

Figure 1. Ratio of area-level probability to the adjusted overall predicted probability indicating areas with lower and higher than expected proportions of overweight among men

Reference category: aged 18-24, single, high income, university diploma, eats less than five fruits or vegetables per day, smokes, physically active, and lives in an urban area materially and socially privileged. Source: Canadian Community Health Survey, 2003

RESULTS

Multilevel analyses

Table 1 presents results of the unadjusted and adjusted logistic multilevel models for men and women. Most demographic, socio-economic and lifestyle indicators are associated in the expected way with overweight. Significant ($p < 0.05$) between-area variation in obesity remains after controlling for these individual characteristics, rurality and area deprivation. The ICC of the adjusted models indicates that about 1.08% of the variation among men and 1.59% of the variation among women can be attributed to differences between areas. Although the ICC for the logistic model is hard to interpret in epidemiologic terms,²² here it can nonetheless be interpreted to suggest that contextual effect appears stronger for women. In the unadjusted model, the area-level OPP of overweight was 55.8% for men and 42.8% for women, which correspond to the estimated prevalence for adults in the province of Quebec.²³ In adjusted models, the OPP decreased by 25% for men and by 34% for women, suggesting a reduction in risk of overweight among people enjoying privileged socio-economic conditions and a predominantly healthy lifestyle.

Second-level residual analyses and cartography

Area-level residual log odds ratios of fully adjusted models were computed into a probability and the associated confidence intervals were used to identify areas that significantly differed from the fully adjusted multilevel model. This allows identifying areas presenting significantly ($p < 0.05$) lower or higher levels of overweight and the extent to which each area differs from what is expected for the 'reference person'. Results are presented in Figure 1 for men and

Figure 2 for women; area probabilities with significantly higher levels of overweight are identified in black, and those with significantly lower levels appear in grey. The geography of overweight appears to follow different regional patterns for men and women, with significant differences in 15 of 51 areas among men, and 17 of 51 among women.

Living in the city centre of Montreal, the largest city in the province, is associated with the province's lowest risk for both men (-22.5%) and women (-38.0%); lower risks of overweight are also observed for people living in Sherbrooke city. Living in (most but not all) middle-size towns south of Montreal is associated with a 5.1% greater risk of being overweight among men only. Women living in the north shore area of Montreal appear to report higher levels of overweight. In the Gatineau area (fifth largest city), men living either in urban or rural areas closer to the urban core present a higher risk of overweight at close to 8%; for women, this probability reaches 28.5%. In the Trois-Rivières area, greater risk of overweight is observed among women, but not men. Two rural areas located near the city of Québec show lower than expected levels of overweight for both women and men.

DISCUSSION

The purpose of this paper is to illustrate and discuss how second-level residual analysis can enhance the interpretation of multilevel area effects on health. Results show that contextual effects on overweight are not distributed evenly between areas, as indicated by different geographic patterns between regions and between men and women. These observations can point to new research questions and hypotheses addressing how the context of different places relates to overweight and obesity levels.

Figure 2. Ratio of area-level probability to the adjusted overall predicted probability indicating areas with lower and higher than expected proportions of overweight among women

Reference category: aged 18-24, single, high income, university diploma, eats less than five fruits or vegetables per day, smokes, physically active, and lives in an urban area materially and socially privileged. Source: Canadian Community Health Survey, 2003

We observed that men living in most middle-size towns close to Montréal, and women living in a similar location north of Montréal, are at greater risk of being overweight. Perhaps this illustrates the influence on body weight of commuting by private motorized transport.¹⁹ Yet this pattern is not observed for women living in the south of Montréal, nor for those living on the outskirts of the city of Québec, the second largest city in the province, although commuting to work by means of private motorized transport is as likely for this area. In the Montréal city centre and in the city of Sherbrooke, the proportions of overweight are lower than expected for both men and women; the specific set of built environment features, resources and services in these regions may be associated with lifestyles among the population that are involved in the aetiology of obesity.

Lower than expected levels of overweight were observed in rural areas on the outskirts of Québec city. These results differ from those of other North American studies which reported a greater prevalence of overweight and obesity in rural than urban areas^{17-19,24,25} but may highlight, as observed elsewhere,^{18,26-28} the existence of inequalities in health between rural areas. Further studies should be conducted to unravel inequalities in overweight between rural areas.

Distinct spatial patterns of overweight were observed for women and men, as well as for regions, indicating that the processes linking place to health may differ by gender and between regional contexts. This highlights the idea that social inequalities in health may be territorialized, or that the specific interaction occurring between socio-economic, demographic, political, and physical contexts may bring about distinct health patterns. Future studies should attempt

to disentangle the differences in contextual influence on overweight and obesity among men and women while taking into account place idiosyncrasies.

Limitations

Results of this study should be interpreted in light of several limitations. The cross-sectional design does not allow for the determination of causal effects. Self-reported height and weight as provided by the CCHS to derive the body mass index is also a well-known source of potential bias.²⁹ The small number of contextual indicators is another limitation. As the province of Quebec encompasses a very large area (1,667,926 km²) with most of its population living in urban settings, data availability is unfortunately not the same all over the territory and this precludes the construction of reliable contextual indicators with the same precision for each area unit. Future studies should attempt to use individual travel information and consider regional mobility patterns for studying the geography of overweight.

CONCLUSION

The observed inequalities between and within regions, as well as between men and women, which were not fully explained by individual or area-level characteristics, are likely to be important in defining actions in public health and public policy at regional and local levels. Many conceptual models of overweight and obesity suggest multi-scale and multi-dimension interventions,^{23,30} yet most intervention programs in the province are of an informational/educational nature and often target behaviour change in 'at-risk' individuals. As Quebec's public health intervention is also administered

at the regional level, some initiatives have been undertaken at a more local scale (Québec-en-forme and Kino-Québec are good examples). However, local interventions are rare, sparse, and mostly based on socio-economic observations; they rarely integrate physical activity and nutrition, and are not supported by a global framework.

Promoting a multi-scale and multi-dimensional framework for public health interventions is not an easy task and must be based on reliable monitoring data. Second-level residuals analysis has the potential to provide important information for the formulation and implementation of regional and local health promotion and prevention strategies by illustrating that contextual effects in relation to overweight (or any health outcome) might be linked to different area-level factors in different environments.

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RÉSUMÉ

Objectifs : Utiliser les résidus de second niveau issus d'une analyse multiniveau pour comprendre le rôle du milieu de vie sur la santé et pour visualiser les endroits dans la province de Québec (Canada) ayant un niveau d'excès de poids significativement différent de la moyenne provinciale.

Méthodes : Les données individuelles d'un échantillon de 20 449 personnes proviennent de l'Enquête sur la santé des collectivités canadiennes (Cycle 2.1) et sont liées à 51 secteurs géographiques. Suite à une régression logistique multiniveau visant à explorer les caractéristiques individuelles et des milieux associées au surpoids, les résidus de second niveau associés aux secteurs géographiques ont été calculés. La cartographie de ces résidus informe sur les secteurs qui présentent un risque de surpoids supérieur ou inférieur à la prévalence provinciale ajustée.

Résultats : En contrôlant pour les caractéristiques socioéconomiques et les habitudes de vie des individus, de nets patrons de distribution d'excès de poids ont été observés distinctement pour les hommes et les femmes, ainsi que pour les régions. Ceci indique que les processus qui mettent en lien le milieu de vie et l'excès de poids peuvent différer selon le sexe et le contexte géographique. En comparaison à la prévalence ajustée de la province, la probabilité de surpoids varie jusqu'à 23 % pour les hommes et 38 % pour les femmes qui vivent dans des conditions privilégiées.

Conclusion : L'analyse et la cartographie des résidus de second niveau produisent une information multi-échelle qui peut permettre d'améliorer la compréhension de la distribution territoriale de la santé et justifier la réalisation d'interventions pertinentes à l'échelle régionale et locale.

Mots clés : excès de poids; obésité; Québec; géographie médicale; analyse multiniveau; santé publique