Region-level obesity projections and an examination of its correlates in Quebec

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ABSTRACT

OBJECTIVES: Regional public health policy-makers frequently adopt obesity programs and objectives that have been established at global, provincial/state or national levels. However, the presence of substantial inter-regional disparities could render this practice inefficient. Studies that collectively assess obesity prevalence, temporal trends and their heterogeneity at the region level are rare, though they could be used to support better regional surveillance and planning. To address this gap, our study projected obesity prevalence time series to 2023 for 16 health regions in Quebec. We also compared the extent to which yearly rates of increase (or slope) versus cross-sectional prevalence drove regional heterogeneity and correlated with obesity-related socio-demographic and behavioural characteristics.

METHODS: Projections were done using weighted compositional regression to fit and extrapolate obesity prevalence time series (1987–2012). Heterogeneity in obesity prevalence as a function of time and obesity slope were characterized using standard deviation. The correlation of region-level obesity prevalence and slope with 14 area-level obesity-related characteristics was assessed.

RESULTS: Obesity prevalence is projected to increase in all regions. Region-level heterogeneity in prevalence in 2012 (σ = 2.2%) is projected to increase to (σ = 3.1%) by 2023. The increase in prevalence heterogeneity appeared to be driven by region-level heterogeneity in slope (β = 0.22%–0.51%/year). Obesity-related characteristics were found to be more strongly correlated with slope than with prevalence.

CONCLUSION: Large area obesity trends mask substantial and increasing region-level disparities. Obesity slope appears to drive region-level heterogeneity and correlate strongly with explanatory factors, and may represent a pertinent metric for public health monitoring.

KEY WORDS: Obesity; epidemiology; public health

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

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Obesity programs and objectives are typically established at the global, national or provincial/state levels.[1–3] However substantial heterogeneity in population health, risk factors and environment is often observed regionally, potentially rendering inefficient any planning and target setting based on information at these high levels.[4,5] While most regional health jurisdictions have their own surveillance programs, there remains a lack of studies that collectively assess and compare inter-regional obesity levels and temporal trends within larger administrative territories. This gap in information could mask important region-level disparities, which could in turn hinder the effectiveness of obesity programs at high levels or their implementation at the regional level.

In addition, obesity surveillance and risk factor burden typically rely on cross-sectional prevalence rather than time trends. Prevalence measures provide "snapshots" of burden, i.e., the average proportion of a given population that is obese at a given time. These have formed the basis for monitoring and target setting in public health. For instance, the World Health Organization's (WHO) obesity-related target is to "halt the rise" in prevalence, while its recent report outlines prevalence estimates in hundreds of countries to monitor trends.[6] Understanding and forecasting trends is an essential component of public health planning,[7] but cross-sectional prevalence measures cannot directly provide the information for these. Further, associations between obesity prevalence and associated characteristics are difficult to interpret because these factors can have a cumulative effect over time that drives the observed prevalence. For instance, longitudinal analyses have found stronger correlations between child poverty and overweight at later time points than earlier ones.[8,9] The strength of prevalence–risk factor associations observed at given points are thus dependent on the time when they happened to be measured.

Rather than prevalence, incidence, i.e., the number of new cases per year, is often considered the most useful metric in epidemiologic studies, but data are scarce. The mean annual change (or time trend) in obesity prevalence can be closely related to yearly incidence because the condition is generally long-term.[10] The slope metric also has less inertia than prevalence,

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making it more readily altered by interventions. Trend information can thus be used to understand past and future burden and provide information on the longitudinal associations of behaviours and characteristics with obesity, supporting public health planning. Such factors include income and education,[11,12] smoking,[13] immigrant status,[14,15] stress,[16–19] social capital,[20,21] and rural vs. urban environment,[22–24] which can drive region-level heterogeneity in obesity as well as predict future obesity burden. However, understanding region-level variation in these behaviours and characteristics in relation to obesity is also usually limited to associations with obesity prevalence, rather than correlated with its time trend. The results of such an assessment would be useful for impact assessment of public health interventions and programs, as well as for planning future objectives.

The objectives of the current study are thus to i) construct historical time series (1987–2012) and projections (2013–2023) of obesity prevalence for 16 health regions in Quebec, Canada to assess region-level obesity, time trends and heterogeneity, and ii) compare the yearly rate of change of obesity prevalence vs. cross-sectional prevalence for explaining observed heterogeneity and as a correlate with region-level obesity correlates.

METHODS

Data source and variables

Obesity

Time series in obesity prevalence were constructed for the adult population (age 18+) in 16 of 18 health regions in Quebec. Data were extracted from 13 cross-sectional survey cycles that spanned 25 years (1987–2012) and comprised three surveys: the Quebec Health Survey (1987)[25] and the Quebec Health and Social Survey (1992–1993, 1998),[26] which were conducted by the Quebec Statistics Institute, and the Canadian Community Health Survey or CCHS (2000–2001, 2002, 2003, 2005, 2007, 2008, 2009, 2010, 2011, 2012)[27,28] which was conducted by Statistics Canada. These surveys excluded two remote and sparsely populated regions in Quebec, Nunavik and Terres Cries de la Baie James, which together represent less than 1% of the population. Women who were pregnant at the time of the survey were also excluded. All surveys are weighted at the health-region level to produce reliable estimates of region-level variables. Survey data and values were extracted from master files for all cycles.

Body mass index (BMI) was calculated as the self-reported weight in kilograms divided by the square of the height in metres. Continuous BMI values were then classified into 3 categories: obese ($BMI \geq 30$), overweight ($25 \leq BMI < 30$) and a combined normal–underweight category ($BMI < 25$). The projection analysis method made use of prevalence trends in all three categories though only the results of the obesity category are retained for presentation and discussion.

Correlates of Obesity

Fourteen commonly accepted behavioural and socio-demographic characteristics associated with obesity were extracted for each health region from Canadian Census data, the Labour Force Survey and CCHS cycles from the year 2000 or 2001 until the most recently available year for each data source (2006, 2011 and 2012 respectively). These correlates were aggregated into means or percentages at the health-region level. The variables and their assessment are displayed in Table 1.

All data were completely de-identified, and access and use adhered to Statistics Canada and the *Institut de la statistique du Québec* confidentiality rules.

Statistical analysis

All analyses were done in R version 3.11 (R Foundation for Statistical Computing, Vienna, Austria. Available at: http://www.R-project.org/).

Projection Analyses

Projections of obesity prevalence were done by fitting to and extrapolating trends in the age- and sex-aggregated prevalence time series of each region. The weighted compositional regression approach was used, which fits and projects all BMI categories together, accounting for their multinomial nature as well as for heterogeneity in survey variance structure.[3] For the current study, only the linear scenario was retained, which assumes that future prevalence time trends will be an approximately linear extrapolation of historical trends.

Table 1. Spearman rank correlations between region-level prevalence or mean value (for continuous correlates) of obesity correlates and i) 2011–2012 regional obesity prevalence; ii) regional obesity mean yearly increase (1987–2012)

Region-level obesity correlates (mean value over stated years per region)	i) Correlation with 2011–2012 obesity prevalence	ii) Correlation with mean yearly increase in obesity prevalence
Weekly hours of TV (CCHS: 2000, 2007, 2008, 2011, 2012)	0.35	0.56
Weekly hours sedentary (CCHS: 2000, 2007, 2008, 2011, 2012)	–0.08	–0.31
Mean level of energy expenditure (CCHS: 2000, 2007, 2008, 2011, 2012)	–0.07	–0.52
% recent immigrants (<5 years) (census: 1991, 1996, 2001, 2006)	–0.26	–0.67
% employed in last 12 months (CCHS: All cycles)	–0.18	–0.54
% reporting high stress (CCHS: All cycles)	0.03	–0.22
% strong sense of community belonging (CCHS: All cycles)	0.06	0.30
% at least university education (CCHS: All cycles)	–0.58	–0.79
% smokers (CCHS: All cycles)	0.47	0.25
% consuming recommended daily fruits/vegetables (CCHS: 2000, 2003, 2007–2012)	0.20	0.00
Mean total revenue (census: 1991, 1996, 2001, 2006)	–0.10	–0.42
% below poverty line (census: 1991, 1996, 2001, 2006)	–0.08	–0.23
% residents living rurally (census: 1991, 1996, 2001, 2006)	0.04	0.36
% residents 65+ years of age	–0.16	0.19

Assessment of Region-level Heterogeneity in Obesity Prevalence and Slope

Past and projected region-level obesity trends were characterized by prevalence as well as mean yearly increase (slope). The prevalence estimates for each year up to 2011–2012, and for 2023, came from the compositional regression described above. A slope reflecting the average increase in obesity prevalence per year was estimated from a linear regression of year versus prevalence in each region. R^2 was used to confirm the goodness of fit of the linear trend in each region. Heterogeneity in the region-specific slopes over time and in regional prevalences in specific years was measured using standard deviation. This resulted, first, in a single standard deviation measuring the "spread" of slopes and, second, in a time series of standard deviations constructed from the yearly spread of obesity prevalences that enabled quantifying changes in heterogeneity over time.

Regional-level Correlation Between Obesity Correlates and Obesity Metrics

We chose 14 risk factors to reflect the concepts discussed above while removing redundant variables, based on the literature review and examination of the degree to which the variables correlated with each other. Correlations between region-level explanatory factor prevalence and rate of change, and obesity prevalence and rate of change, were measured over the 14 factors. This resulted in four sets of correlation coefficients: one for each respective prevalence and rate of change combination. Obesity prevalence estimated from the 2011–2012 CCHS full cycle was used to represent current prevalence, while the obesity rate of change was estimated as the linear slope from 1987 to 2012 as described. The prevalence of obesity-related behaviours and characteristics corresponded to the mean prevalence from ≈2007–2012 to reflect current prevalence; their rate of change was estimated as the linear slope from 1991 to 2006 (for census-derived variables) or 2000 to 2012 (for CCHS-derived variables). The correlation between regional obesity and the mean prevalence and rate of change of associated behaviours and characteristics was calculated using the Spearman rank correlation method, which is robust toward possible non-linearity and outliers. The Spearman correlation can be interpreted as the degree to which region-level variation or ranking in each risk factor (prevalence or slope) is associated with the observed region-level variation or ranking in obesity (prevalence or slope).

Two separate sensitivity analyses were conducted to evaluate the robustness of the results (see Supplementary file Appendix 1 and 2 for full explanation. Note: All supplementary material in this article can be accessed in the ARTICLE TOOLS section on the journal site): 1) The possible impact of "shrinkage to the mean" was assessed by applying unequal variance Stein shrinkage to estimates of obesity prevalence and slope;[29] 2) The impact of the difference in statistical precision between obesity prevalence and slope estimates was assessed by making use of fitted (rather than measured) obesity prevalence estimates.

RESULTS

Projection analyses

The overall prevalence of obesity in Quebec was projected to increase from 18% in 2012 to 24% in 2023. Obesity was also projected to increase in all 16 health regions in Quebec, though the 2023 projected obesity levels varied greatly (see Figure 1 for obesity prevalence curves over time).

Assessment of regional heterogeneity

Overall, obesity increased at an average rate of 0.38% per year over historical (1987–2012) time trends (95% confidence interval [CI] = 0.35–0.41). Trends for the prevalence of obesity in each region from 1987 to 2012 were generally strongly linear, as demonstrated by high R^2 values (>0.8) in all regions. The exceptions were Regions 7, 13 and 10, where the variance explained by the linear trend is reduced because of flatter trends (Table 2 for all results).

We found substantial regional heterogeneity in both obesity prevalence and its rate of increase or slope (Figure 2). In 2012, the measured obesity prevalence ranged from 15% to 23% with an estimated standard deviation (SD) = 2.2%. Given that in 1987, SD = 1.3%, region-level heterogeneity in obesity prevalence has increased markedly over time. This heterogeneity is projected to increase further in the future to SD = 3.1% in 2023. The increasing heterogeneity in prevalence appears to be driven by differential slopes that ranged from 0.22% to 0.51% per year. For example, in 1987, Region 1 and Region 3 had similar prevalences (6.33% and 6.23% respectively) but Region 1 had a steeper slope (0.43 vs. 0.35). The result was approximately a 3.6% difference in projected prevalence by 2023 (Table 2). Adjusting for shrinkage to the mean in obesity prevalence and slope estimates did not substantially change these findings (see Supplementary file Appendix 2 for detailed results).

Regional-level correlation between explanatory factors and obesity metrics

Spearman correlation coefficients (ρ) between obesity slope and regional-level prevalence of obesity-related behaviours and characteristics were generally equal or higher in magnitude as compared to the correlations between obesity prevalence and explanatory factor prevalence (Table 1), with the correlations generally in the same direction. For instance, the ranking of having higher percentage of recent immigrants was more strongly correlated with the ranking of regions' rate of increase than actual obesity prevalence ($\rho = -0.67$ vs. $\rho = -0.26$). This, and three other characteristics (% employed, mean number of weekly TV hours, and % with at least a university education) also exhibited moderate correlations with obesity prevalence but stronger correlations with obesity rate of increase. Mean energy expenditure, poverty prevalence, rural status, reporting high stress, and having a strong sense of community belonging had Spearman correlations near 0 with obesity prevalence, but correlations with obesity rate of increase were at least of moderate strength (see Table 1).

While almost all the obesity correlates showed stronger correlations with obesity rate of increase than with obesity prevalence, there were some exceptions. Rankings of percent who smoke and percent who report eating recommended levels of fruit and vegetable were more strongly associated with regional obesity prevalence rankings than rates of increase ($\rho = 0.47$ vs. $\rho = 0.25$; $\rho = 0.20$ vs. $\rho = 0.0$ respectively). Also, regions with a higher proportion of the population aged 65+ had lower prevalence of obesity but faster rates of increase ($\rho = -0.16$ vs. $\rho = 0.19$),

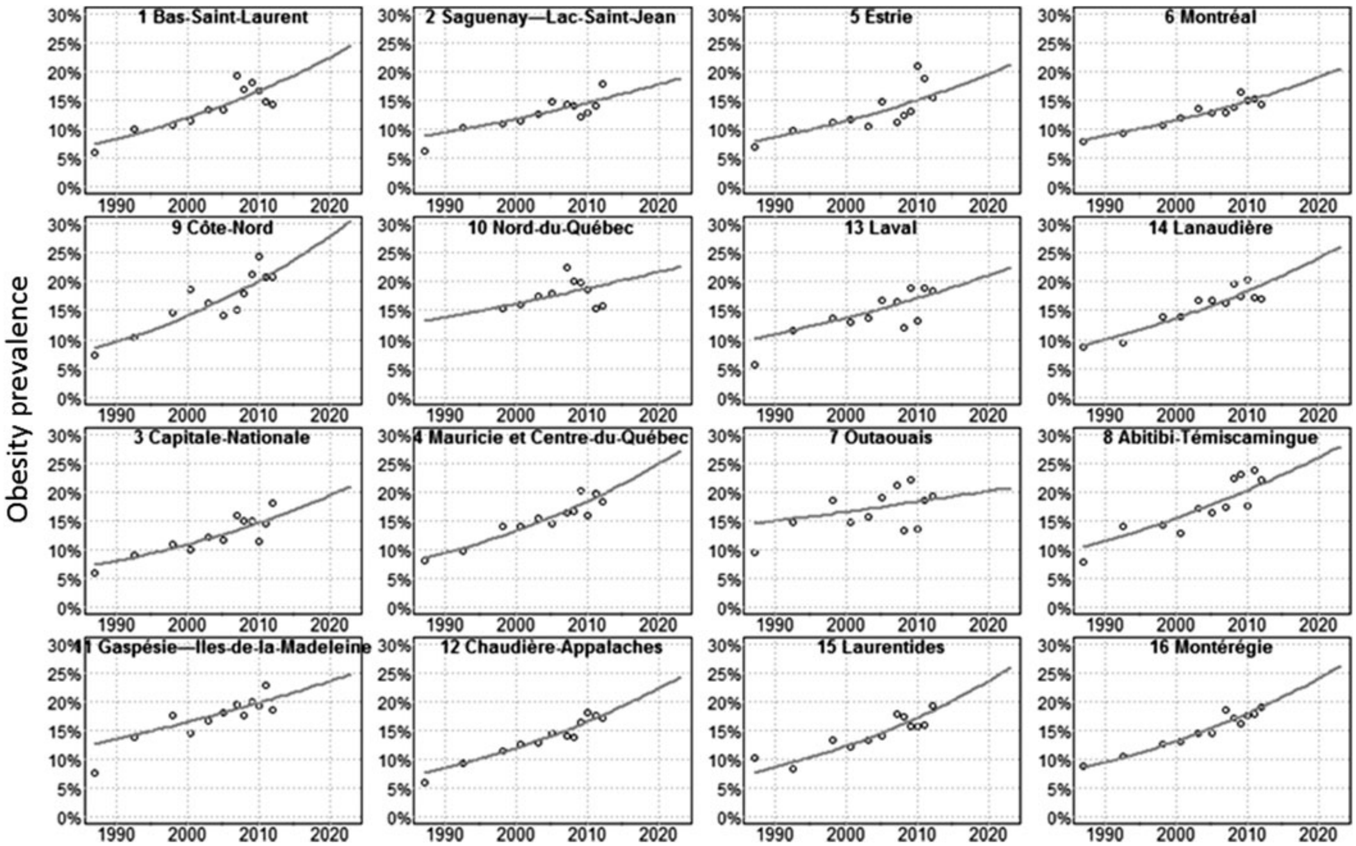

Figure 1. Historical obesity prevalence time series (1987–2012) and projection to 2023

Table 2. Mean yearly increase in obesity prevalence (1987–2012) with R^2 goodness of fit, survey estimated obesity prevalence in 1987 and 2011, projected obesity prevalence in 2023, and variation between regions (standard deviation)

Region	Mean yearly increase in obesity prevalence (95% CI)*	$R^{2\dagger}$	1987 survey estimated obesity prevalence‡	2011–2012 survey estimated obesity prevalence§	2023 projected obesity prevalence‖
[1] Bas Saint Laurent	0.43 (0.34; 0.53)	0.90	6.1	14.6	25
[2] Saguenay	0.34 (0.25; 0.43)	0.86	6.3	16.0	18.9
[3] Capitale nationale	0.35 (0.23; 0.46)	0.80	5.9	16.2	21.0
[4] Mauricie et centre du Québec	0.45 (0.37; 0.53)	0.93	8.0	19.0	27.1
[5] Estrie	0.31 (0.18; 0.44)	0.72	7.1	17.1	21.2
[6] Montréal	0.30 (0.24; 0.36)	0.93	7.9	14.7	20.4
[7] Outaouais	0.29 (0.05; 0.54)	0.36	9.4	18.9	20.7
[8] Abitibi	0.51 (0.35; 0.67)	0.81	7.9	22.9	27.8
[9] CÔte Nord	0.51 (0.38; 0.64)	0.87	7.4	20.8	30.5
[10] Nord-du-Québec	0.22 (−0.07; 0.51)	0.18	N/A	15.7	22.6
[11] Gaspésie – Îles-de-la-Madeleine	0.48 (0.32; 0.64)	0.80	7.6	20.7	24.7
[12] Chaudière-Appalaches	0.44 (0.39; 0.49)	0.97	6.1	17.4	24.3
[13] Laval	0.39 (0.21; 0.57)	0.66	5.5	18.7	22.5
[14] Lanaudière	0.43 (0.33; 0.53)	0.90	8.7	17.1	26.1
[15] Laurentides	0.36 (0.23, 0.49)	0.76	10.2	17.6	25.9
[16] Montérégie	0.40 (0.34, 0.45)	0.95	8.7	18.4	26.1
Standard deviation	0.08	–	1.3	2.0	3.1

* Estimated from linear regression of obesity prevalence on time (year).
† R^2 indicates goodness of fit of the linear regression used to estimate mean yearly increase.
‡ 1987 prevalence estimates were obtained from the Quebec Health and Social Survey.
§ 2011–2012 prevalence estimates were obtained from the Canadian Community Health Survey.
‖ 2023 prevalence estimates were obtained from projections of historical time series (1987–2012).

showing correlations in opposite directions. In contrast, regions with higher prevalence of obesity had a greater proportion of residents reporting high levels of stress, but lower rates of obesity increase.

Sensitivity analyses completed using Stein estimation attenuated the correlation values, but the same pattern was generally observed. Further sensitivity analysis using model-fitted obesity prevalence shows that while region-level explanatory factor

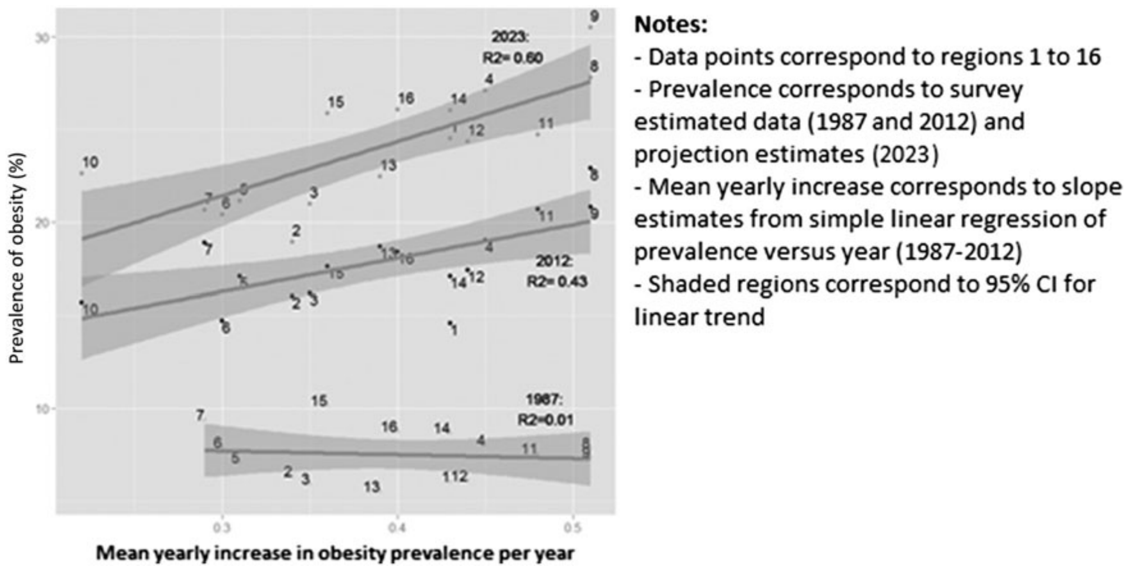

Figure 2. Obesity prevalence versus mean yearly increase (slope) for 1987, 2012 and 2023. Note: Data points correspond to regions 1–16. Prevalence corresponds to survey estimated data (1987 and 2012) and projection estimates (2023). Mean yearly increase corresponds to slope estimates from simple linear regression of prevalence versus year (1987–2012). Shaded regions correspond to 95% CI for linear trend

correlation with obesity prevalence increases, the correlation with obesity slope remains comparatively stronger (see Supplementary file Appendix 1 and 2 for detailed results).

DISCUSSION

While obesity is projected to increase in all health regions in Quebec to 2023, there is substantial inter-regional heterogeneity in both 2012 prevalence (SD = 1.32) and mean rate of increase (slope) (0.22%–0.51%/year). This heterogeneity in prevalence is forecast to increase to 2023 (SD = 3.06) if current trends continue. These findings suggest that regional obesity trends will diverge to an increasing extent into the future.

Our results indicate that the yearly increase in obesity (slope) may be a useful alternative metric to the typically-used prevalence for regional public health monitoring. The increasing differences in prevalence over time appear to be driven by differential slopes between regions rather than differences in baseline prevalence. Relatively higher correlation with average region-level behaviours and characteristics further underscores the utility of obesity slope as an indicator of interest for monitoring and use in programs. Variables associated with rate of increase but not with obesity prevalence, such as percent living below the poverty line, may exert a continual pressure over time. Indeed, longitudinal analyses find a stronger correlation between child poverty/deprivation and overweight at later time points than at earlier ones.[8,9] Similarly, the change in proportions of different demographic groups can potentially provide more insight into the future obesity burden than the current proportions for planning purposes.

The value of measuring obesity slope from time trends of prevalence for public health may also lie in its ability to approximate yearly incident cases (see Supplementary file Appendix 3). The proportion of *new* cases of obesity each year possibly provides a better reflection of the impact of public health interventions. In contrast, obesity prevalence distributions, like many other prevalence health indicators, represent the cumulative effect of all previous experience,[30] and may be less responsive to current conditions and interventions. Other recent literature has underscored the relevance of incidence measures to more deeply understand increasing rising obesity prevalence over the past few decades and the lack of studies to this effect.[31–33]

Despite the potential importance of slope or yearly increase, public health authorities almost exclusively focus on prevalence when planning reduction targets. For example, obesity prevalence is the primary performance indicator: in Quebec's *Plan d'action gouvernmental*;[34] for major US jurisdictions, including New York City;[35] for the Council of Australian Governments;[36] and even for WHO.[6] Only the United Kingdom's action plan for England states as an ambition, "a downward trend in the level of excess weight averaged across all adults by 2020", possibly referring to slope, though the quantitative target was unclear.[37] Our study suggests that target setting in terms of slope may be an additional possibility to monitor progress towards a longer-term obesity reduction goal.

There are some limitations to our findings. First, though heterogeneity at even finer, intra-region scales has been noted,[38,39] the health region scale chosen for the current study represents the smallest jurisdiction mandated provincially to implement programs. Second, we did not have access to potentially important environmental indicators that could drive regional disparities, such as those measuring the built environment,[40] limiting us to inclusion of aggregated individual-level risk factors. However the Spearman correlations suggest possibilities for further exploration in terms of differences between regions rather than causal relationships. Third, we could not stratify by age due to small sample sizes, so age distributions are a possible confounder for the obesity projections, though a province-level projection study found that obesity trends were not driven by changes in population age structure,[3] and our projection estimates were further limited to 10 years to reduce possible error due to this limitation. Finally, the use of self-reported BMI means that the obesity prevalence estimates represent underestimations of actual prevalence,[41] though time trends, heterogeneity and correlation results for risk factors are expected to hold.

CONCLUSION

While both historical and projected time trends show an increase in obesity to 2023 for all 16 health regions in Quebec, there are nevertheless substantial and increasing intra-regional disparities in both prevalence and rate of increase. Region-level yearly increases in obesity, as compared with cross-sectional prevalence, appear to drive increasing heterogeneity as well as being more strongly correlated with population-level behaviours and characteristics. Prevalence time trend (or slope) may thus represent a useful and pertinent metric for monitoring, intervention planning and program targets.

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RÉSUMÉ

OBJECTIFS : Les décideurs de politiques de santé publique régionaux appliquent souvent des programmes et objectifs relatifs à l'obésité établis à l'échelle provinciale ou nationale. Cependant, d'importantes disparités régionales suggèrent que cette pratique serait inefficace. Les études évaluant collectivement la prévalence, les tendances temporelles et leur hétérogénéité à l'échelle régionale pourraient soutenir les décideurs, mais elles sont peu nombreuses. Afin de répondre à cette lacune, nous avons effectué des projections jusqu'à 2023 sur des séries temporelles de la prévalence de l'obésité pour 16 régions sociosanitaires du Québec. Nous avons aussi comparé l'hétérogénéité régionale pour la pente reliant les prévalences annuelles à celle pour la prévalence annuelle considérée transversalement, ainsi que la corrélation entre chacune de ces mesures et les caractéristiques sociodémographiques et comportementales associées à l'obésité.

MÉTHODES : Les projections ont été faites grâce à la régression compositionnelle pondérée pour ajuster et extrapoler les séries temporelles de la prévalence de 1987–2012. L'ampleur de l'hétérogénéité régionale dans la pente des prévalences annuelles et dans la prévalence annuelle transversale est estimée par l'écart-type. La corrélation entre chacune des mesures de prévalence à l'échelle régionale avec 14 caractéristiques liées avec l'obésité ont été estimées par la méthode de Spearman.

RÉSULTATS : Les analyses de projections suggèrent une augmentation de la prévalence de l'obésité dans toutes les régions étudiées. On projette que l'hétérogénéité régionale de la prévalence augmentera entre 2012 (σ = 2,2 %) et 2023 (σ = 3,1 %). Cette augmentation dans l'hétérogénéité de la prévalence provient de l'hétérogénéité régionale observée avec la pente (β = 0,22 %–0,51 %/année). La corrélation entre les caractéristiques associées à l'obésité était également plus importante avec la pente.

CONCLUSION : Les tendances de l'obésité à grande échelle masquent des disparités importantes et grandissantes à l'échelle régionale. La pente des prévalences annuelles semble révéler le mieux l'hétérogénéité régionale et est fortement corrélée aux caractéristiques associées à l'obésité. Cette mesure pourrait être un indicateur pertinent pour la surveillance et la planification sociosanitaire.

MOTS CLÉS : obésité; épidémiologie; santé publique