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QUANTITATIVE RESEARCH

Population-level trends in the distribution of body mass index in Canada, 2000–2014

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Abstract

Objective Research studying population-level body mass index (BMI) trends document increases in mean or prevalence of overweight/obese but less consideration has been given to describing the changing distribution of BMI. The objective of this research was to perform a detailed analysis of changes in the BMI distribution in Canada.

Methods Using data from the CCHS (2000–2014), we analyzed distributional parameters of BMI for 492,886 adults aged 25–64 years. We further stratified these analyses for women and men, education level, and region of residence.

Results Mean BMI has increased for most subgroups of the Canadian population. Mean BMI values were higher for men, while standard deviation (SD) of the BMI distribution was systematically higher in women. Increases in mean BMI were accompanied with increases in SD of BMI across cycles. Across survey cycles, the 95th percentile increased more than 10 times more rapidly compared to the 5th percentile, showing a very unequal change between extreme values in the BMI distribution over time. There was a relationship between SD with BMI, but these relations were generally not different between educational categories and regions. This suggests that the growing inter-individual inequalities (i.e., dispersion) in BMI were not solely attributable to socioeconomic and demographic factors.

Conclusions This study supports the hypothesis that the simultaneous increases in mean BMI and SD of the BMI distribution are occurring, and suggests the need to move beyond the mean-centric paradigm when studying a complex public health phenomenon such as population change in BMI.

Résumé

Objectif Les recherches populationnelles portant sur l'évolution de l'indice de masse corporelle (IMC) rapportent une augmentation de la moyenne et de la prévalence de l'embonpoint/obésité, mais accordent moins d'intérêt aux changements distributionnels. L'objectif de cette recherche était de réaliser une analyse détaillée des changements distributionnels de l'IMC au Canada.

Méthodologie À partir des données de l'ESCC (2000–2014), nous avons analysé les paramètres distributionnels de l'IMC de 492,886 adultes âgés de 25 à 64 ans. Les analyses ont été stratifiées entre les femmes et les hommes, le niveau d'instruction et la région de résidence.

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Résultats L'IMC moyen a augmenté pour la majorité des sous-groupes de la population canadienne. Les valeurs de l'IMC moyen étaient plus élevées pour les hommes, alors que celles de l'écart-type (É-T) de la distribution de l'IMC étaient systématiquement plus élevées chez les femmes. L'augmentation de l'IMC moyen était accompagnée d'une augmentation de l'É-T de l'IMC à travers les cycles. À travers les cycles de l'enquête, le 95ème percentile augmentait plus de dix fois plus rapidement que le 5ème percentile, révélant un changement très inégal entre les valeurs extrêmes de la distribution de l'IMC dans le temps. Il y avait une relation entre l'É-T et l'IMC, mais de façon générale, ces relations n'étaient pas différentes entre les catégories du niveau d'instruction et de la région de résidence. Ceci suggère que la croissance des inégalités interindividuelles de l'IMC n'est pas uniquement attribuable à des facteurs socioéconomiques et démographiques.

Conclusions Cette étude supporte l'hypothèse que la croissance de l'IMC moyen et de l'É-T de la distribution de l'IMC se produisent de façon simultanée et suggère le besoin d'aller au-delà du paradigme de recherche centré sur la moyenne pour l'étude de phénomènes de santé publique complexes comme celui de l'évolution de l'IMC à l'échelle des populations.

Keywords Body mass index · Trends · Education · Sex · Canada

Mots-clés Indice de masse corporelle · Tendance · Instruction · Sexe · Canada

Introduction

The worldwide increase in obesity and related chronic diseases is recognized to be driven in part by global trade liberalization, economic growth, and rapid urbanization (Hawkes 2006; Kelly and Fuster 2010; Popkin et al. 2012). These factors continue to influence important changes in living environments, diets, and lifestyles in ways that promote positive energy balance (Malik et al. 2013). The rise in body mass index (BMI = kg/m^2) is often reported in the research literature and in public health reporting as prevalence of specific BMI categories (e.g., overweight or obese) or as mean change (NCD-RisC 2017). For example, the increase of the average BMI has been 0.5 kg/m^2 per decade globally; this rate was shown to be faster in wealthier countries such as the USA and Canada where the rate of increase in BMI was over 1 kg/m^2 per decade (Finucane et al. 2011).

Research studying BMI trends in developed countries suggests that along with increase in overall mean BMI, differential increases have occurred within subpopulations grouped by sex, race, and socioeconomic status (SES) (McLaren 2007). Some studies revealed a slight negative inflection of the BMI growth curve potentially due to a leveling off of the rise in mean BMI within countries (Flegal et al. 2012; Krueger et al. 2014; Twells et al. 2014). However, most of these studies do not take account of the changing shape of the BMI distribution with time and assume that BMI increases at a proportional rate within all categories (NCD-RisC 2017). Few studies have examined whether inequalities in weight gain are occurring within social groups or specific segments of the population, which is a measure of interindividual inequalities rather than between-group inequalities (Vaezghasemi et al. 2016). An increasing body of work suggests that bringing a distributional perspective to BMI changes may reveal important information about population health (Green et al. 2016; Krishna et al. 2015) and may contribute to the discussion on the relative merits of the population strategy compared with the high-risk strategy (Razak et al. 2016).

Motivated by this concern, Krishna et al. (2015) showed that increase in mean BMI in the US was correlated to the increase in the spread of the BMI distribution, suggesting that mean BMI cannot fully describe population changes in BMI. Moreover, they showed a similar increase in dispersion within socioeconomic and demographic groups, suggesting that growing inequalities in BMI at the population level are not driven solely by individual factors. A recent analysis came to a similar conclusion in England (Green et al. 2016). In Canada, weight categories were observed to evolve at different rates in the general adult population without taking into account individual determinants of obesity (Twells et al. 2014). Other Canadian studies showed significant geographic variations in BMI above individual determinants of obesity such as age, sex, education level, and lifestyle indicators (Dutton and McLaren 2016). Detailed sociospatial description of the BMI distributional changes in Canada over time may contribute to prior reporting which often focused on point estimates (mean or prevalence), geographic variation, or a specific period, and for which the dispersion is rarely the focus (Twells et al. 2014; Dutton and McLaren 2016; Gotay et al. 2013). This work will also allow comparison to BMI distributional changes observed in Canada versus other high-income countries and among subgroups of the population commonly associated with BMI (Green et al. 2016; Krishna et al. 2015).

The objective of this research was to perform a detailed analysis of the BMI distribution changes in Canada by sex, education level, and region of residence.

Methods

Data sources

Data were retrieved from the Canadian Community Health Survey (CCHS), a multiple cross-sectional health survey performed by Statistics Canada since the year 2000. The CCHS provides self-reported information for a nationally representative sample of the non-institutionalized civilian population 12 years and older in the 10 Canadian provinces, excluding territories (Statistics Canada). Data collection for the first three cycles was every 2 years: cycle 1.1 (2000–2001), cycle 2.1 (2003), and cycle 3.1 (2005). Samples were approximately 130,000 Canadian individuals per cycle. From the 4th cycle, the data collection was performed annually and included about 65,000 individuals per year. To standardize data collection, the annual investigations have been grouped as follows: 2007–2008 (cycle 4); 2009–2010 (cycle 5); 2011–2012 (cycle 6); 2013–2014 (cycle 7).

Study population and sample size

We restricted the analyses to those 25 to 64 years of age in order to be consistent with previous work using distributional change in BMI (Green et al. 2016; Krishna et al. 2015). Moreover, because of an artificial increase of BMI due to shrinkage in stature in older adults (Sorkin et al. 1999), the use of BMI may not be appropriate to compare older individuals with younger ones (Ogden et al. 2007). We also excluded pregnant women and individuals with missing data on key variables of interest such as sex, BMI value, and those living in households where the highest education level was not reported. We also excluded extreme BMI values that are often considered to be extreme outliers or reporting errors (12<BMI>70 = less than 1% observations) (Lebel et al. 2014). The 25–64-year subsample represents 59% of the CCHS sample for all cycles. Exclusion criteria represent 8% of the subsample. CCHS sample weights were normalized to take account of the sample plan and the exclusion criteria (Statistics Canada 2011). The final sample included 492,886 individuals (Table 1).

Outcome

The distribution of BMI was the outcome of interest. BMI is measured as a ratio of weight (kg) to the square of height (m). The 5th and 95th percentiles and the standard deviation (SD) of the BMI distribution were used as outcomes to study changes in the shape of the distribution over time relative to the median and the mean of BMI.

Table 1 Distribution of pooled CCHS sample of adults age 25–64 years, 2000–2014

Variable	Women	Men
Sample size	242,201.3	250,684.7
Proportion	49.1%	50.9%
Age group		
25–29	11.6%	12.2%
30–34	11.4%	12.1%
35–39	13.1%	13.1%
40–44	14.6%	14.8%
45–49	14.1%	13.7%
50–54	13.7%	13.1%
55–59	11.8%	11.7%
60–64	9.7%	9.4%
Education		
No high school	11.3%	12.7%
High school	18.0%	16.9%
College	44.7%	44.6%
Graduate studies	26.0%	25.7%
Region		
Atlantic	7.5%	7.2%
Quebec	24.0%	24.0%
Ontario	38.9%	38.4%
Prairies	6.0%	6.2%
Alberta	10.2%	10.9%
British Columbia	13.4%	13.2%
Cycle		
1 (2001–2002)	49.1%	50.9%
2 (2003–2004)	48.9%	51.1%
3 (2005–2006)	49.0%	51.0%
4 (2007–2008)	49.5%	50.5%
5 (2009–2010)	49.3%	50.7%
6 (2011–2012)	48.9%	51.1%
7 (2013–2014)	49.3%	50.7%

Key independent variables

The key independent variables were sex, age stratified into 5-year groups, and education level stratified into four categories based on number of years at school and diploma attainment (Lebel et al. 2014). The “No diploma” category includes those who had been less than 12 years at school or more than 12 years at school but had no diploma. The “High school” category includes only those who successfully finished high school (secondary-5 diploma or 13th year completed). The “College” category includes all those who did some post-secondary, with or without a college diploma, including those who received a university certificate (e.g., 1 year at the university). Finally, the “Graduate studies” category includes those with a baccalaureate diploma or higher.

The BMI and SD distributions trends were also disaggregated by province. Since Canadian provinces greatly vary by population size, some of them were grouped into regions comparable to other Canadian studies describing spatial dispersion of BMI (Dutton and McLaren 2016; Gotay et al. 2013): Saskatchewan and Manitoba were named the Prairie region, and Newfoundland, Prince Edward Island, New Brunswick, and Nova Scotia are known as the Atlantic provinces.

Graphical analysis of patterns in BMI distributional changes in time

We used quantile-quantile (QQ) plots to examine patterns of distributional change in BMI (Krishna et al. 2015; Wilk and Gnanadesikan 1968). A QQ plot was constructed by plotting percentiles of BMI from the most recent survey (2013–2014) against percentiles of BMI from the baseline survey (2000–2001). If there were no change in distributions between the two survey cycles, the points would lie on the line of the equality ($y = x$). Points above the line represented increases in BMI at the same percentile in the most recent year from baseline. QQ plots are particularly effective in presenting changes at the tails of distributions (Wilk and Gnanadesikan 1968). We constructed QQ plots separately for women and men.

Analysis of BMI distribution trends

CCHS data from 2000 to 2014 were pooled to allow for the comparison of distributional changes over time. We conducted analyses by sex, educational level, and region of residence to disaggregate distributional changes within subgroups of the population. Stratifying by sex, we had two subgroups; stratifying by educational level and sex, we had eight subgroups; for the stratification by region and sex, we had 12 subgroups.

To estimate the BMI distribution trends, ordinary least square (OLS) regressions were used for modeling the mean, the SD, and the BMI value at the 5th and 95th percentiles. For analyses on the entire sample, we adjusted BMI for age, sex, and educational level. When stratifying by sex, by sex and educational level, or by sex and region, we adjusted only for age. CCHS sample weights were normalized for each subgroup analysis. Thus, each analysis was weighted according to the subsample population size.

Analysis of the relation of distributional parameters of BMI

To fully characterize the distribution trends, we further analyzed the relationship between centrality indicators of the BMI distributions (mean and median) predicting their dispersion indicators (SD, and 5th and 95th percentiles). Changes in mean BMI were related to the SD of BMI (spread of the distribution) and changes at the 5th and 95th percentiles of BMI (extremities or tails of the distribution) were related to the median (50th percentile).

In this study, we utilized standard deviation (SD) and percentiles of the BMI distribution as measures of inequality to assess the population-level dispersion across individuals within groups. The theoretical framework of our study is based on what Murray and Gakidou defined as "health inequality," which is variation in health status across individuals in a population (Gakidou et al. 2000; Murray et al. 1999) This approach aims to complete the measurement of social group inequalities by differences in mean values or the prevalence of health outcomes between social groups more frequently used (Vaezghasemi et al. 2016).

Fitted OLS regression lines for changes in these distributional parameters over time were plotted for women and men as well as subgroups disaggregated by educational levels and the six Canadian regions. For all models, units of analysis were survey cycles (2-year groups; $n = 7$ cycles). Model significance tests were conducted using t tests; differences in changes between categories were tested using Wald tests. All analyses were performed using SAS 9.4.

Results

Table 1 shows a distribution of the CCHS pooled sample for 2000–2014 surveys. The final sample comprised 492,886 Canadian adults proportionally distributed across age groups, education level categories, and regions.

Graphical analysis of patterns of BMI distributional changes in Canada

Comparing the BMI mean at multiple points in the distribution revealed that lower BMI subgroups of the population had very little change in the mean BMI, while the higher BMI subgroups showed a substantial increase (Fig. 1). For both women and men, we observed a similar pattern indicating a progressive augmentation in the mean BMI for subgroups of the population having a higher mean BMI at baseline.

Analysis of BMI distribution trends in Canada

Figure 2 shows the evolution of four distributional parameters of the BMI distribution for women and men: the mean BMI, its SD, the value at 5th and 95th percentiles. These parameters were stratified by sex, by sex and education level, and by sex and the region of residence. Detailed results of the OLS parameter estimations are available in Supplementary Table 1.

The mean, the SD, and the value at 95th percentile significantly increased between 2000 and 2014 ($p < 0.05$), while the value at 5th percentile increased very slightly

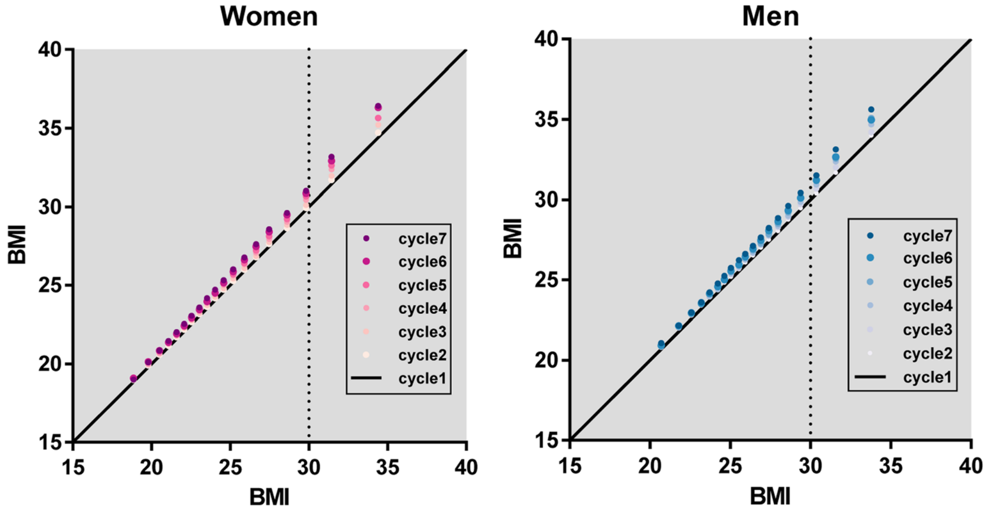

Fig. 1 Evolution of the distribution of BMI for women and men in Canada, 2000–2014

($p < 0.10$). The 95th percentile increased by 0.33 BMI/cycle which is more than 10 times the increase for the 5th percentile (0.029 BMI/cycle).

Stratification by sex Mean BMI and SD increased significantly for women and men during the 15-year period. The increase in the 5th percentile was significant only for men. The 95th

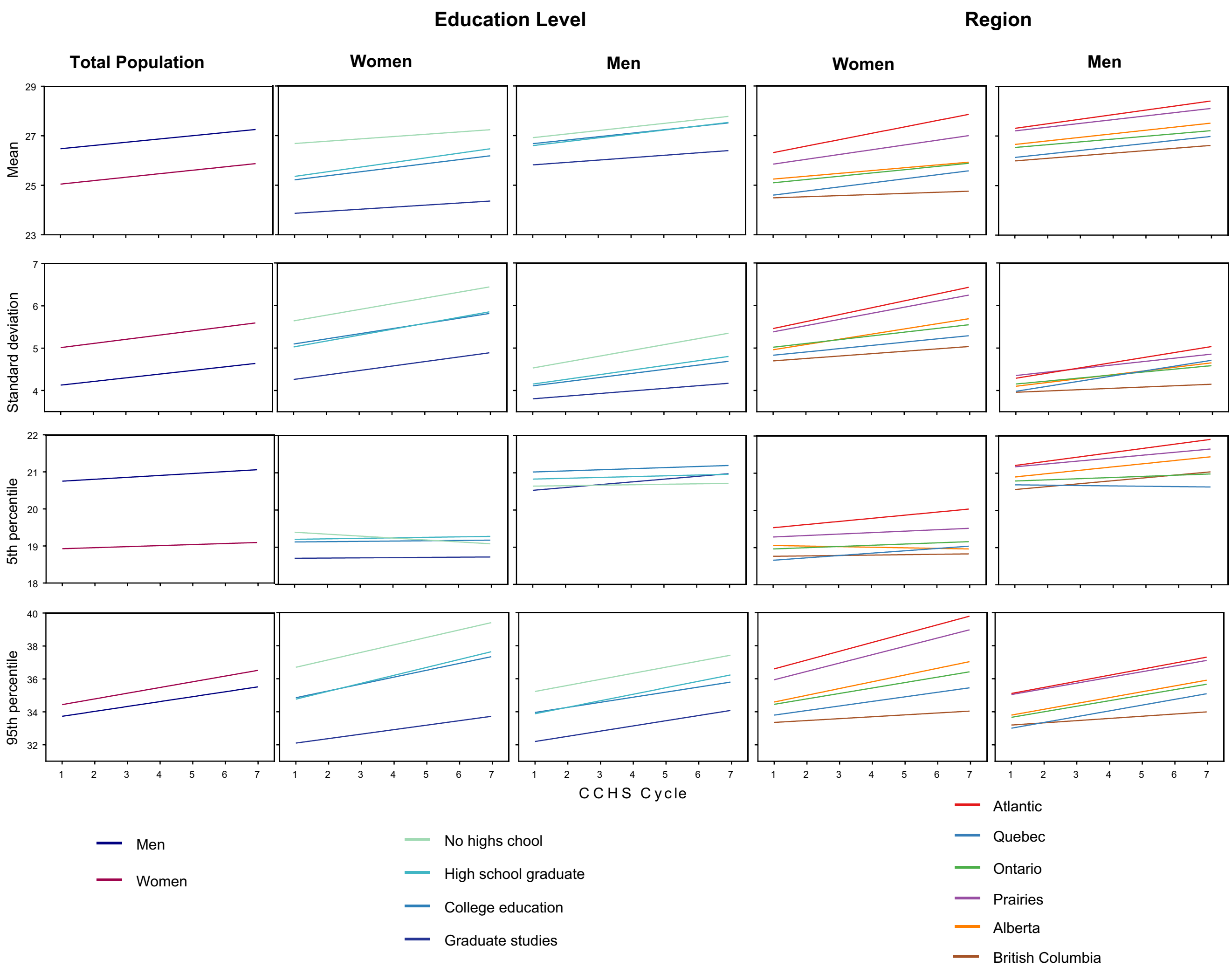

Fig. 2 Evolution of BMI distributional parameters in CCHS from 2000 to 2014 for women and men and by education level and region of residence

percentile significantly increased for both, the increase was slightly higher for women (0.35 kg/m^2 per cycle in women; 0.30 kg/m^2 per cycle in men), but no significant differences were observed between women and men in the evolution of all four parameters.

Stratification by sex and education level We observed a significant increase in mean, SD, and 95th percentile of BMI for women in all education level categories. There was a marked and significant difference in the mean and the 95th percentile between educational levels, suggesting the BMI distribution evolves differently for women according to their education level. The increase in the 95th percentile was substantially less for women with graduate degrees versus all other groups.

For men, although mean, SD, and 95th percentile of the BMI distribution increased significantly for all educational groups, no statistical difference was observed between them. At the 5th percentile, the value of the SD tended to increase faster for men without a high school degree than other educational categories (p value < 0.10) and increased at the same pace as the mean (0.14 BMI/cycle).

Stratification by sex and region of residence All four BMI distributional parameters increased significantly for women in all Canadian regions, except for British Columbia (BC) where no increase was observed on any of the distributional parameters over 15 years, and in Alberta where the value of the 5th percentile stayed about the same. Taken globally, the increases of the mean and 5th and 95th percentiles were statistically different between regions. This regional variation was particularly spread for the mean and the 95th percentile, suggesting that the change in the BMI distribution among women varies according to the region of residence.

The mean, SD, and 95th percentile also increased significantly for men in all Canadian regions. The increase at the 5th percentile was also significant for most regions, and only Ontario and Quebec showed a relatively stable value during the study period. Although the between-region variation was less pronounced than that for women, the increase of all four distributional parameters was significantly different between the six Canadian regions.

Overall, Fig. 2 shows that BMI was consistently higher for men over the 15-year period, while the SD was systematically higher for women. The mean, SD, and 95th percentile increased for all educational levels for both sexes. Changes in these three parameters were also observed in all Canadian regions, and where the increase in the 95th percentile was especially pronounced for both sexes.

Relative changes in distributional variables of BMI

Figure 3 shows the relation between dispersion indicators and centrality indicators of the BMI distribution, the relation between the SD and the mean BMI, and the relation between the 5th and 95th percentiles and the median BMI. Detailed results of the OLS parameter estimations are available in Supplementary Table 2.

Stratification by sex An increase in mean BMI was significantly associated with an increase in the SD for both women and men. The value at the 5th percentile did not increase significantly in women. However, the 95th percentile was estimated to rise by 3.27 kg/m^2 for an increase of 1 kg/m^2 in the median. This suggests that an increase in the BMI median value is driving an increase over three times greater at the 95th percentile of the distribution. Since the BMI value at the 5th percentile did not change significantly, these observations demonstrate that this subgroup of the population saw a flattening of its BMI distribution.

In men, there was a significant increase in the 5th percentile (0.52 kg/m^2) as well as for the 95th percentile (2.75 kg/m^2), suggesting that the distribution curve is simultaneously flattening and moving toward higher BMI values.

Stratification by sex and education level An increase in women's mean BMI was associated with an increase of the SD in all educational categories, but no significant differences were observed between education levels.

For men, we also observed that an increase of the mean BMI was associated with an increase in SD in all educational categories, but without significant difference between them. No significant relationship was observed between the 5th percentile and the median of the distribution except with regard to most educated men. This subgroup showed an increase of the 5th percentile that almost matched the increase of the median (0.99 kg/m^2), suggesting that the educated men's BMI distribution is not flattening and is globally moving toward higher BMI values.

Stratification by sex and regions The increase of the women's mean BMI significantly resulted in an augmentation of the SD in all Canadian regions. The increase of the BMI dispersion was particularly large among BC women (1.11 kg/m^2) as compared to other regions such as Quebec (0.48 kg/m^2) or the Atlantic (0.65 kg/m^2), resulting in a statistically significant difference in the SD-BMI relationship between regions (p = 0.041). Most regions showed a positive relationship with an increase in the median BMI for the 95th percentiles, but no significant difference was observed between regions.

For men, all associations with the SD with mean BMI showed a positive and significant relationship, but no significant difference was observed between regions. A similar relationship was observed between the 95th percentiles and the median, but again no significant difference was observed between regions.

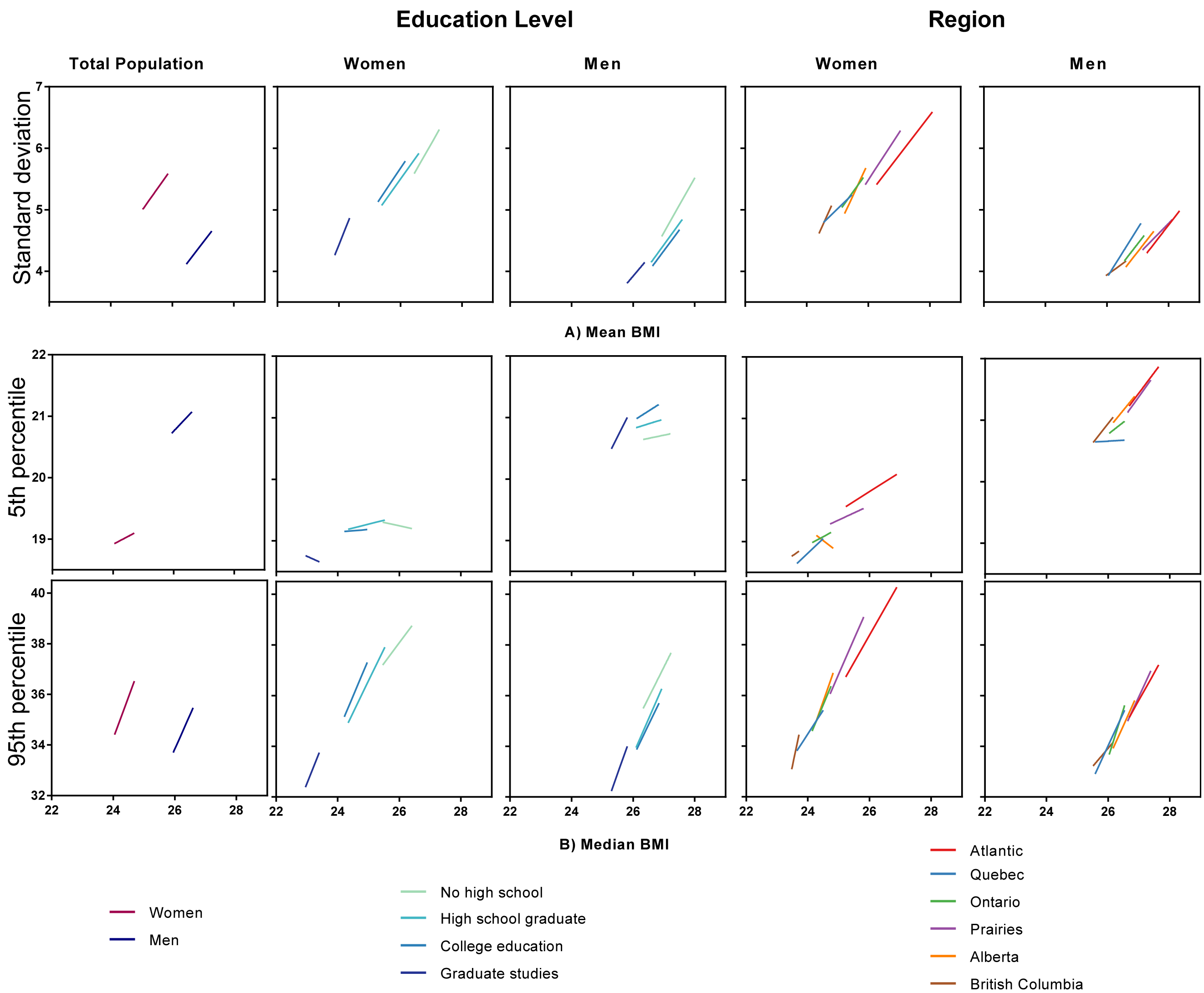

Fig. 3 BMI distributional variables' association with centrality indicators for men and women, by education level and region of residence

Discussion

This study presents a detailed analysis of trends in BMI variation in Canada by sex, education level, and province of residence, and has two main findings. First, the mean BMI increased over time at different paces according to the education level or the geographic location, and was generally accompanied by an increase in dispersion (SD, 5th and 95th percentiles range). Second, most dispersion indicators were positively and significantly associated with centrality measures, but taken globally, these relationships were not statistically different between women and men, between education levels, and between Canadian regions. Finding an increase of the mean BMI during the last 15 years was expected. However, the fact that this BMI increase goes along with an increased dispersion which can actually predict the BMI increase, independently of sex, education, and geographical context, has never been clearly demonstrated in Canada.

Previous population research linking individuals' BMI with SES in high-income countries showed that individuals with lower SES, those with lower educational attainment or working in lower grade occupation, are more likely to have higher BMIs than individuals in higher-SES groups (McLaren 2007; Silventoinen et al. 2013; Neuman et al. 2013). Longitudinal studies showed that both adults and children of low SES are more likely to become obese than those in higher-SES groups, with more pronounced differences in women (Baum 2nd and Ruhm 2009; Howe et al. 2011). Our findings are in concordance with those observations, but went slightly further by demonstrating that increase in BMI dispersion occurs in most subgroups of the population independently of SES.

Our results also support other studies suggesting the context in which one lives could also have an influence on obesity indicators (Twells et al. 2014; Dutton and McLaren 2016; Gotay et al. 2013; Lebel et al. 2014). In effect, the evolution of all four distributional parameters, including the 5th percentile, varies significantly when the analyses are stratified by sex and regions. These differences are partly driven by the observations in BC where no significant trend was observed for women, and a much lower increase of the mean, SD, and 95th percentile for men. Paradoxically, the BMI of men in the 5th percentile in BC showed a greater increase than that for men in other regions such as Quebec or Ontario. Underlying these specific sex-context trend scenarios, we further observed there were practically no significant differences between subgroups of the population in the relationship between distributional parameters and the centrality measures (mean and median). This suggests that the growing interindividual inequalities (i.e., dispersion) in BMI were not solely attributable to demographic, socioeconomic, and geographic factors in Canada. Said differently, the increasing BMI dispersion occurs in a similar way within all subgroups of the population and everywhere in Canada.

These observations confirm that the Canadian population is experiencing a similar phenomenon to what was recently observed in the USA (Krishna et al. 2015) and the UK (Green et al. 2016). This systematic increase in dispersion suggests that other causes, such as unmeasured genetic, physiologic, or social characteristics, might be at work. The biological mechanism of fat distribution in the body differs between women and men and may partly explain why the BMI distribution is more variable in women (Tchernof and Després 2013). However, it is not clear whether only the biological differences are involved in this variation since social perception concerning weight status may also vary by gender (i.e., social roles), and thus provide different daily opportunities and constraints regarding weight-related behaviours.

Other theories have been proposed and discussed to explain increasing dispersion at the individual level (Jenkins and Campbell 2015; Frohlich and Potvin 2008; Kivimäki et al. 2015), and many suggest this may be the result of the interaction between the individuals' genetic susceptibility and environment factors (Jenkins and Campbell 2014; Razak et al. 2015). These new findings put forward several unanswered questions. Why does the mean BMI sometimes evolve differently between men and women in the same region (Glymour and Spiegelman 2017)? Could this be linked to provincial policies, social norms, or local urban planning practices (World Health Organization 2014)? Which underlying mechanisms are at play in the increasing dispersion we observed in all the population? (Merlo 2011) Are there unmeasured genetic characteristics which make some individuals more vulnerable to some specific contextual characteristics? (Ludwig et al. 2011) Besides presenting trends in BMI change and variation, this study contributes to an increasing body of evidence that supports researchers and policy makers in moving away from a mean-centric paradigm (Merlo 2011) when investigating important public health issues such as the obesity epidemic. A better understanding of the underlying variability mechanisms in space and time needs to be considered in order to propose adapted interventions, rather than narrowing the observations on point estimates such as mean or prevalence (Razak et al. 2016).

The detailed analysis of trends in BMI variation in Canada had to deal with several challenges and resulted in some limitations. The self-reported BMI increased the uncertainty of measurements, which may also differ between women and men. The correlation between measured and self-reported BMI in Canada was estimated at 0.89 (Shields et al. 2011); we assumed this bias was constant through the CCHS cycles, and we stratified analyses by sex to control for the gender effect. Merging many survey cycles may bring some systematic biases due to a modification in the sampling strategy or in the questionnaire. The large and consistent sample by cycle of the CCHS is a strength of this research and reduces potential biases that could be introduced by methodological changes in time. We verified that the BMI-related questions were the same for all cycles and we made sure the educational level was comparable in time and between regions by creating the categories on the reported number of years at school and diploma attainment. The number of subgroups that were analyzed and compared may have introduced some ambiguity in the results. Nevertheless, we are confident the overall results strongly support our interpretation.

Conclusion

This study shows that the increase in mean BMI was associated with increased group and interindividual inequalities in weight gain in different social and demographic groups in Canada. It contributes to the understanding of this complex causal web behind rising BMI, by highlighting the evolution of the BMI distribution and variation between sex, education level, and region of residence. In turn, this leads to new relevant research questions that may help to address underlying social forces that drive the obesity epidemic in high-income countries.

Although great effort was made to enhance healthy lifestyle and lower obesity rate in Canada, limited success was achieved during the last decade. (Gotay et al. 2013) Besides presenting trends in BMI change and variation, this study contributes to an increasing body of evidence that supports researchers and policy makers in moving away from a mean-centric paradigm when investigating important public health issues such as the obesity epidemic, and to also consider the variability of the phenomenon in order to propose adapted interventions.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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