Editor's key points

- This study used data from the Canadian Primary Care Sentinel Surveillance Network to examine trends in excess weight among 243 078 patients accessing primary care who had body mass index (BMI) values recorded in their electronic medical records.
- The authors found a modest increase in mean BMI of 2.1% between 2011 and 2016. Using an average height in Canada of 168.7 cm (175.1 cm in men and 162.3 cm in women), this increase can be translated to a 1.7-kg (3.7-lb) increase in body weight over the study period, or to more than half a pound annually. The estimated prevalence of obesity increased from 32.2% in 2011 to 38.2% in 2016. By 2016, the estimated prevalence of excess weight (overweight and obese BMI values) was 72.1%.
- For both sexes, BMI showed an increase with age up to approximately age 75, when there was a dramatic decline in BMI. Further, BMI tended to increase most rapidly in younger adults (18 to 34 years); those in older age groups tended to have higher BMI values that remained stable over time.

Recent trends in adult body mass index and prevalence of excess weight

Data from the Canadian Primary Care Sentinel Surveillance Network

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Abstract

Objective To explore recent body mass index (BMI) trends over time among Canadian adults seen in primary care to identify the best target groups for preventive interventions.

Design Retrospective descriptive cohort design.

Setting Data for this study were derived from the Canadian Primary Care Sentinel Surveillance Network database.

Participants All patients aged 18 years and older who had BMI measurements available between 2011 and 2016 were identified. A closed cohort (N = 243 078 unique patients) with a start date of January 1, 2011, was defined. Patients were excluded if key variables were missing or if BMI measurements were 15 kg/m^2 or less or 50 kg/m^2 or greater.

Main outcome measures The dependent variable for this study was BMI (kg/m^2). Measured BMI values recorded in electronic medical records were used. A linear mixed-effect estimate was fit to model changes in BMI over time with control of baseline age and sex.

Results Patients in the Canadian Primary Care Sentinel Surveillance Network database experienced a modest increase in mean (95% CI) BMI by 2.1% from 28.5 (28.4 to 28.6) kg/m^2 in 2011 to 29.1 (28.9 to 29.2) kg/m^2 in 2016 (P < .0001). This increase is not a measured difference in BMI in the same individual but reflects the difference in the average BMI of the population in 2011 versus 2016. Male patients had BMI values that were on average 1.02 kg/m^2 higher than those of female patients (P < .0001). Mean BMI values increased most rapidly in young adults (18 to 34 years) compared with older adults.

Conclusion The findings indicate that current obesity management in primary care is failing to moderate weight trajectories in different groups by age and sex. The results also suggest that younger age groups, in whom accelerated weight gain occurred, should be the target of prevention initiatives.

Tendances récentes dans l'indice de masse corporelle chez l'adulte et prévalence du surpoids

Données du Réseau canadien de surveillance sentinelle en soins primaires

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Résumé

Objectif Explorer les tendances récentes dans l'indice de masse corporelle (IMC) au fil du temps chez des adultes canadiens vus en soins primaires pour identifier les meilleurs groupes à cibler par des interventions de prévention.

Type d'étude Étude de cohortes descriptive et rétrospective.

Contexte Les données pour cette étude étaient tirées de la base de données du Réseau canadien de surveillance sentinelle en soins primaires.

Participants Tous les patients de 18 ans ou plus dont les mesures de l'IMC étaient accessibles entre 2011 et 2016 ont été identifiés. Une cohorte fermée (N = 243 078 patients uniques) a été définie, et ce, à compter du 1er janvier 2011. Les patients étaient exclus si des variables clés étaient absentes ou si les mesures de l'IMC étaient de 15 kg/m^2 ou moins, ou de 50 kg/m^2 ou plus.

Principaux paramètres à l'étude La variable dépendante dans cette étude était l'IMC (kg/m^2). Les valeurs mesurées de l'IMC consignées dans les dossiers médicaux électroniques ont été utilisées. Une estimation linéaire à effets mixtes a été adaptée pour modéliser les changements dans l'IMC au fil du temps en fonction de l'âge et du sexe au départ.

Résultats Les patients inclus dans la base de données du Réseau canadien de surveillance sentinelle en soins primaires ont connu une hausse modeste de leur IMC moyen (IC à 95 %) de 2,1 %, passant de 28,5 (28,4 à 28,6) kg/m^2 en 2011 à 29,1 (28,9 à 29,2) kg/m^2 en 2016 (p < ,0001). Cette augmentation n'est pas la différence mesurée dans l'IMC chez la même personne, mais elle reflète plutôt la différence dans l'IMC moyen de la population étudiée en 2011 par rapport à 2016. Les hommes avaient des valeurs moyennes de l'IMC de 1,02 kg/m^2 supérieures à celles des femmes (p < ,0001). Les valeurs moyennes de l'IMC augmentaient plus rapidement chez les jeunes adultes (18 à 34 ans) en comparaison de celles des adultes plus âgés.

Conclusion Les constatations indiquent que la prise en charge actuelle de l'obésité en soins primaires ne réussit pas à modérer les trajectoires pondérales dans différents groupes selon le sexe et l'âge. Les résultats font aussi valoir que les groupes d'un plus jeune âge, chez qui le gain pondéral s'est produit plus rapidement, devraient être la cible des initiatives de prévention.

Points de repère du rédacteur

- Cette étude s'est fondée sur des données du Réseau canadien de surveillance sentinelle en soins primaires pour examiner les tendances dans le surpoids chez 243 078 patients ayant reçu des soins primaires et dont les valeurs de l'indice de masse corporelle (IMC) étaient consignées dans leur dossier médical électronique.
- Les auteurs ont constaté une hausse modeste de 2,1 % de l'IMC moyen entre 2011 et 2016. En se fondant sur une hauteur de taille moyenne de 168,7 cm au Canada (175,1 cm chez les hommes et 162,3 cm chez les femmes), cette augmentation peut se traduire par un gain de 1,7 kg (3,7 lb) en poids corporel durant la période à l'étude ou de plus d'une demi-livre par année. La prévalence estimée de l'obésité est passée de 32,2 % en 2011 à 38,2 % en 2016. Dès 2016, la prévalence estimée d'un excès de poids (surpoids et obésité selon les valeurs de l'IMC) se situait à 72,1 %.
- Tant chez les hommes que les femmes, on a constaté une augmentation de l'IMC avec l'âge jusqu'à environ 75 ans, suivie d'un déclin considérable dans l'IMC. De plus, l'IMC avait tendance à augmenter plus rapidement chez les adultes plus jeunes (18 à 34 ans); les personnes d'âge plus avancé avaient tendance à avoir des valeurs de l'IMC plus élevées qui demeuraient stables avec le temps.

Excess body weight (overweight and obese body mass index [BMI] values) is associated with higher mortality rates driven by comorbidities such as cardiovascular diseases, type 2 diabetes, hypertension, and certain types of cancer.[1] Obesity and obesity-related health problems also impose a burden on health care resources, mainly through excess service use.[2] Obesity is a complex syndrome that is not only associated with a range of chronic diseases but that also, by itself, has recently been recognized as a chronic disease by several influential health and medical organizations, including the World Health Organization (WHO) and the Canadian, European, and American medical associations.[3] The prevalence of excess weight continues to rise and has reached alarming levels around the world; this has been described as a global pandemic by some authors.[4-6] The prevalence of obesity in Canada almost doubled in a 30-year span, rising from 14% in 1981 to 25% in 2009.[7,8] The 2015 adult obesity practice guidelines from the Canadian Task Force on Preventive Health Care noted that approximately two-thirds (62%) of Canadian adults aged 18 to 79 had excess body weight BMI of ≥25 kg/m^2).[7,8] Most recent estimates regarding the distribution of BMI and the prevalence of obesity in Canada come from 2 nationally representative cross-sectional surveys, the Canadian Community Health Survey (CCHS) and the Canadian Health Measures Survey (CHMS).[9-12] The CHMS cycle 5 (2016-2017) data showed that 61% of Canadian adults aged 18 to 79 were either overweight (34%) or obese (27%) according to their BMI based on directly measured height and weight. However, the sample sizes for these objectively measured values in CHMS cycles are small (approximately 5000 in each cycle).[13] The CCHS population BMI estimates are derived from self-reported heights and weights, which are known to underestimate BMI.[14]

The Canadian Primary Care Sentinel Surveillance Network (CPCSSN) provides a unique opportunity to access longitudinally measured BMI data obtained through primary care electronic medical records (EMRs) over time. The only previous study of BMI trends using CPCSSN data found a steady increase in the estimated prevalence of obesity from 17.9% in 2003 to 30.8% in 2012.[15] Our aims in the current study were to determine the proportion of patients in the CPCSSN sample falling into each of the WHO-defined BMI categories,[16] both overall and stratified by age, sex, and time; to explore trends in BMI over time among Canadian adults seen in primary care; to compare the distribution of BMI estimated using the CPCSSN primary care sample with those obtained from representative national surveys (ie, CCHS and CHMS); and to model longitudinally expected BMI over time, controlling for covariates such as baseline age and sex to find subgroups in urgent need of early detection and intervention in this setting.

Methods

Data source and study design

We used a retrospective descriptive cohort design[17] and applied the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) checklist for reporting observational studies.[18] The data used in this study were derived from the CPCSSN database. The overall architecture and approach of CPCSSN has been previously described in detail.[19,20] Data for comparison with the CCHS and CHMS were provided by Statistics Canada.

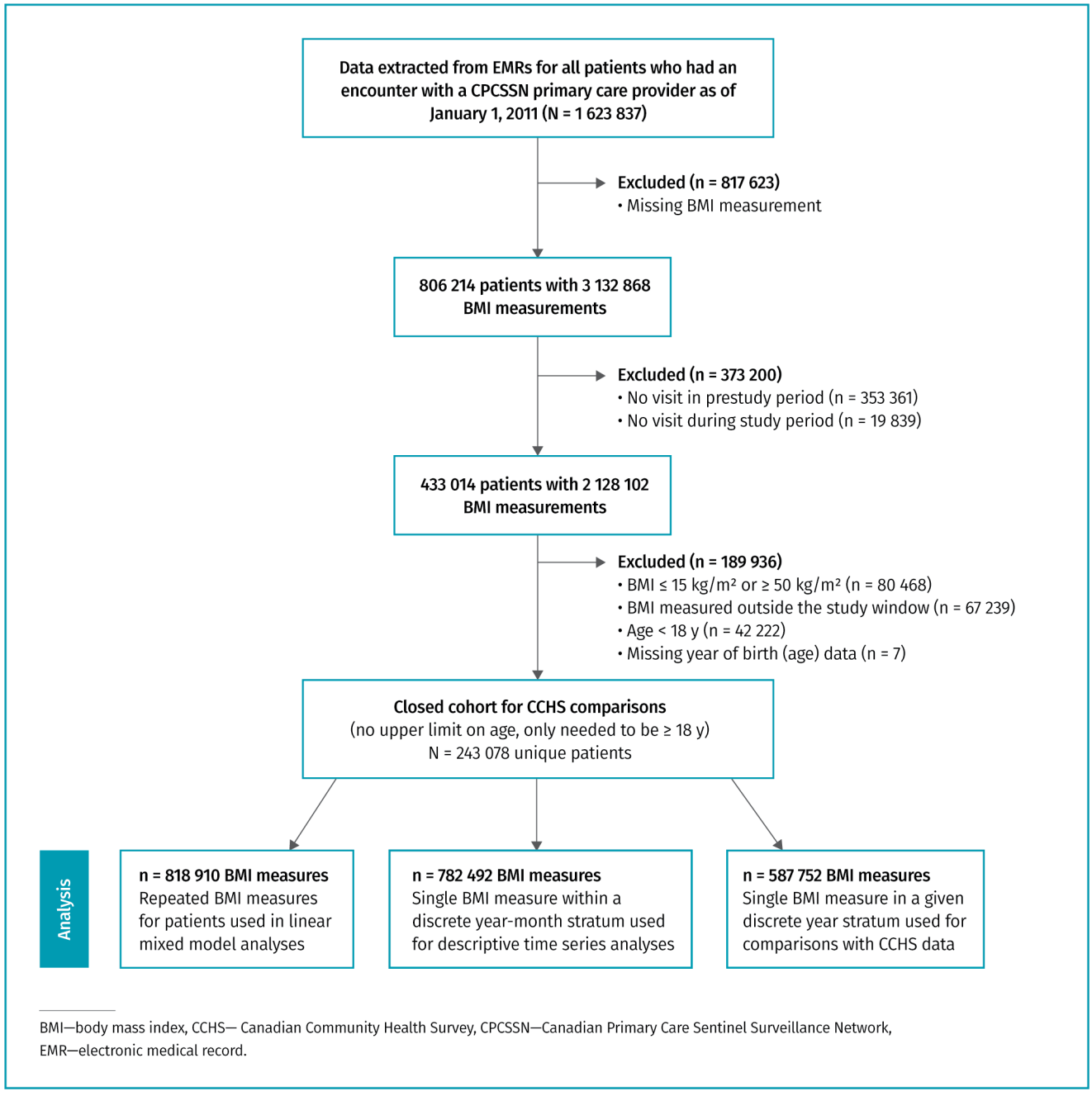
Study population

A flowchart of the study population selection is displayed in **Figure 1**. Our entire CPCSSN data repository contained 1 623 837 records of patients aged 18 years and older. We defined a closed cohort with a start date of January 1, 2011. All patients were included if they had had at least 1 visit in the 2 years preceding this start date, had had at least 1 visit between January 1, 2011, and December 31, 2016, and had at least 1 BMI measurement recorded in their EMRs during this period. After excluding those patients who met the exclusion criteria (**Figure 1**),[16] a total of 243 078 unique patients remained for analyses. We also defined an open cohort wherein participants included both those enrolled in the closed cohort as well as those new recruits entering CPCSSN between January 1, 2011, and December 31, 2016. Although the open cohort includes a larger number of unique patients, we did not use it for primary analyses, as CPCSSN network recruitment could lead to dynamic changes in mean patient age or changes in the male-to-female ratio in the sample over time; this might have affected the prevalence of BMI classes or the rates of change. However, the open cohort design was used for sensitivity analyses.

Variables of interest and case definition for obesity

The dependent variable for this study was BMI (kg/m^2). We used the measured BMI values recorded in the EMRs. If a patient had multiple BMI values available in a particular time interval, one was randomly selected and used. The BMI values were categorized according to WHO recommendations as underweight (<18.5 kg/m^2), normal weight (18.5 to 24.9 kg/m^2), overweight (25.0 to 29.9 kg/m^2), or obese (≥30.0 kg/m^2); obesity was further subcategorized into class I (30.0 to 34.9 kg/m^2), class II (35.0 to 39.9 kg/m^2), and class III (≥40.0 kg/m^2).[15,16,21] We also analyzed BMI as a continuous response variable for time trend and longitudinal modeling. Independent variables included age, sex, and time (month and year, January to December between 2011 and 2016). Age was calculated in years from date of birth to January 1, 2011 (study baseline).

Figure 1. Flowchart illustrating specific inclusion and exclusion criteria applied to the CPCSSN database to obtain our analytic samples



BMI—body mass index, CCHS— Canadian Community Health Survey, CPCSSN—Canadian Primary Care Sentinel Surveillance Network, EMR—electronic medical record.

Statistical analysis

The results are reported as means and 95% CI for quantitative variables and as numbers and percentages for categorical variables unless otherwise stated. We estimated the proportion of patients falling into a given BMI category, stratified by calendar year and further stratified by age and sex. A Wald approach (ie, asymptotic normal limits) was used to generate associated 95% CIs around estimated proportions.[22] If an individual had multiple BMI measures in a given year, a single random observation was used to generate prevalence estimates, such that within a given year we had an independent sample of BMI observations. For comparisons with the national surveys, participants were divided into sex- and age-specific groups. The age groups (18 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, and ≥75 years) were chosen to align with the age groups used for the CCHS, which is the only national data set with sufficient numbers to stratify by age and sex. Estimates were compared with the CCHS surveys in 2011 and 2016, and the

differences were considered statistically significant if there was no overlap between corresponding 95% CIs; overlapping CIs indicate no difference between our sample and CCHS.

To describe trends in mean BMI over time, we used an aggregate descriptive time-series approach. We discretized time into 72 monthly bins (one for each month between January 2011 and December 2016) and computed mean BMI in a given year-month stratum. If a patient had multiple BMI values in a given year-month stratum, a single random observation was considered, and mean BMI over time was stratified by age and sex. Again within a given year-month stratum, we had an independent sample of BMI observations. The time-ordered collection of mean BMI estimates represents a time series, and simple descriptive plots provide a sense of BMI trends over time.

Furthermore, a linear mixed model was fit to model longitudinal BMI measures obtained for a given patient. The linear mixed model was used to account for the nonindependent nature of the data, which arises from repeated BMI measures being obtained for a single patient over time. A random intercept term was included in the model to account for variation in BMI values across different patients. We also used a first-order autoregressive residual correlation structure to account for the temporal dependence between repeated measures of BMI in a given patient over time. The purpose of this analysis was to model (rather than describe) changes in BMI over time, controlling for covariates such as baseline age (categorical) and sex. Linear mixed-model parameter estimates, along with 95% CIs and *P* values, are presented.

A *P* value threshold of $\alpha = .05$ was used for determining statistical significance. All statistical analyses were carried out using R, version 3.5.1, and SAS, version 9.4.

Results

At baseline (January 1, 2011) the mean (SD) age of the sample (243 078 unique patients) was 51.7 (17.4) years and most participants were female (148 124; 60.9%). There were 818 910 repeated BMI measurements. A single BMI measurement was observed for 84 351 people in the sample (34.7%); 158 727 persons in the sample (65.3%) had 2 or more BMI measurements during the study follow-up. The maximum number of BMI measurements observed for a single individual was 152.

Prevalence of excess weight

The estimated prevalence of obesity increased from 32.2% in 2011 to 38.2% in 2016, while the proportion of individuals with a normal weight decreased from 31.7% to 26.4% (**Table 1**).[16] These changes are not a measured difference in BMI in the same individual, but reflect the difference in the average BMI of the population in 2011 versus 2016. Breakdowns of BMI class according to age and sex in 2011 and in 2016 are provided in **Tables 2** and **3**,[16] respectively. As shown, male participants had a higher prevalence of overweight and obese BMI than female participants did; the prevalence of overweight and obese BMI was also higher in older individuals than in younger adults.

Trends over time

We examined changes in BMI among patients in the 6-year study period from 2011 to 2016 stratified by sex and age groups. As depicted in **Figure 2**,[16] mean BMI modestly increased over the course of the study. In January 2011, mean (95% CI) BMI was 28.5 (28.4 to 28.6) kg/m^2 and in December 2016 it was 29.1 (28.9 to 29.2) kg/m^2, which shows an increase of 0.6 kg/m^2 over this time period ($P < .0001$). Mean BMI values were greater in male participants and tended to increase with increasing age. Two time-series plots of average BMI stratified by age group are presented for each sex separately, in **Figure 3** for women and in **Figure 4** for men.[16] These plots empirically demonstrate that in any age group men had a higher average BMI than women did. For both sexes, BMI showed an increase with age up to approximately age 75, when there was a dramatic decline in BMI. Further, BMI tended to increase most rapidly in younger adults (age groups of 18 to 24 years and 25 to 34 years) compared with older adults; those in older age groups tended to have higher BMI values that remained stable over time.

Comparison with national surveys

We requested that Statistics Canada replicate the descriptive analyses we conducted with CPCSSN data using corresponding CCHS and CHMS data. Data from CHMS cycle 3 (2012-2013) and cycle 4 (2014-2015) were not available for comparison owing to extreme sampling variability. The CCHS data using both self-reported and corrected BMIs for years 2011 and 2016 are presented in **Tables A1** to **A4** available from **CFPlus.***
Overall, in the obese class I, II, and III categories, even after correction for "self-reported" height and weight, prevalence estimates were higher in the CPCSSN data than in the corresponding CCHS data. These differences were statistically significant in almost all age and sex groups (**Tables 2** and **3**),[16] as indicated by nonoverlapping 95% CIs for relevant comparisons.

Modeling of longitudinal BMI profiles

As shown in **Table 4,** mean BMI values increased on average 0.06 kg/m^2 per year; this inference is concordant with

*Data from the Canadian Community Health Survey using both self-reported and corrected body mass index measures for years 2011 and 2016 are presented in **Tables A1** to **A4,** available at **https://www.cfp.ca**. Go to the full text of the article online and click on the **CFPlus** tab.

Table 1. Estimates of the percentage of BMI classes in the CPCSSN data sample, stratified by study year: ***N= 587 752 BMI measurements.***

		PREVALENCE ESTIMATE (95% CI), %					
YEAR	N	UNDERWEIGHT* (BMI < 18.5 KG/M²)	NORMAL WEIGHT* (BMI 18.5-24.9 KG/M²)	OVERWEIGHT* (BMI 25-29.9 KG/M²)	OBESE CLASS I* (BMI 30-34.9 KG/M²)	OBESE CLASS II* (BMI 35-39.9 KG/M²)	OBESE CLASS III* (BMI ≥ 40 KG/M²)
2011	117 217	1.4 (1.3 to 1.4)	31.7 (31.4 to 32.0)	34.8 (34.5 to 35.1)	19.7 (19.4 to 19.9)	8.1 (7.9 to 8.3)	4.4 (4.3 to 4.5)
2012	105 564	1.4 (1.3 to 1.5)	31.0 (30.7 to 31.3)	34.8 (34.5 to 35.0)	20.0 (19.8 to 20.3)	8.3 (8.1 to 8.5)	4.5 (4.4 to 4.7)
2013	98 351	1.4 (1.3 to 1.5)	29.9 (29.6 to 30.1)	34.8 (34.5 to 35.1)	20.5 (20.2 to 20.7)	8.7 (8.5 to 8.9)	4.8 (4.7 to 4.9)
2014	95 309	1.4 (1.3 to 1.5)	29.1 (28.9 to 29.4)	34.6 (34.3 to 34.9)	20.8 (20.5 to 21.1)	9.0 (8.8 to 9.2)	5.1 (5.0 to 5.3)
2015	97 008	1.3 (1.2 to 1.4)	28.2 (27.9 to 28.5)	34.3 (34.0 to 34.6)	21.3 (21.1 to 21.6)	9.4 (9.2 to 9.6)	5.5 (5.3 to 5.6)
2016	74 303	1.4 (1.3 to 1.5)	26.4 (26.1 to 26.8)	33.9 (33.6 to 34.3)	22.4 (22.1 to 22.7)	10.0 (9.8 to 10.2)	5.8 (5.7 to 6.0)

BMI—body mass index, CPCSSN—Canadian Primary Care Sentinel Surveillance Network.
*World Health Organization BMI classes.[16]

Table 2. Estimates of the percentage of BMI classes in the CPCSSN data sample, stratified by age and sex, 2011

	PREVALENCE ESTIMATE (95% CI), %					
AGE GROUP, Y	UNDERWEIGHT* (BMI < 18.5 KG/M²)	NORMAL WEIGHT* (BMI 18.5-24.9 KG/M²)	OVERWEIGHT* (BMI 25-29.9 KG/M²)	OBESE CLASS I* (BMI 30-34.9 KG/M²)	OBESE CLASS II* (BMI 35-39.9 KG/M²)	OBESE CLASS III* (BMI ≥ 40 KG/M²)
Total cohort						
• 18-24	5.1 (4.6 to 5.6)	57.8 (56.7 to 58.9)	22.1 (21.1 to 23.0)	9.0 (8.3 to 9.6)	4.0 (3.5 to 4.4)†	2.2 (1.8 to 2.5)
• 25-34	2.3 (2.0 to 2.6)†	44.8 (43.9 to 45.7)	28.1 (27.3 to 28.9)†	13.6 (13.0 to 14.2)	6.6 (6.2 to 7.1)†	4.6 (4.8 to 5.0)†
• 35-44	1.3 (1.1 to 1.5)	36.0 (35.2 to 36.7)	31.6 (30.9 to 32.3)†	17.5 (16.9 to 18.1)	8.2 (7.8 to 8.6)†	5.4 (5.1 to 5.8)†
• 45-54	0.9 (0.8 to 1.0)	29.6 (29.0 to 30.2)†	35.1 (34.5 to 35.7)†	20.5 (20.0 to 21.0)	8.9 (8.5 to 9.2)†	5.1 (4.8 to 5.3)†
• 55-64	0.7 (0.6 to 0.8)	24.1 (23.5 to 24.6)†	36.9 (36.3 to 37.5)†	23.4 (22.9 to 23.9)	10.0 (9.6 to 10.3)†	5.1 (4.8 to 5.3)†
• 65-74	0.6 (0.5 to 0.7)	22.3 (21.7 to 22.9)†	40.1 (39.4 to 40.8)	24.3 (23.6 to 24.9)†	8.9 (8.3 to 9.1)†	4.0 (3.8 to 4.3)†
• ≥ 75	1.5 (1.3 to 1.7)	28.9 (28.1 to 29.7)†	42.2 (41.3 to 43.0)	19.9 (19.1 to 20.6)†	5.8 (5.4 to 6.2)†	1.8 (1.6 to 2.1)†
• All	1.4 (1.3 to 1.4)	31.7 (31.4 to 32.0)†	34.8 (34.5 to 35.1)	19.7 (19.4 to 19.9)†	8.1 (7.9 to 8.3)†	4.4 (4.3 to 4.5)†
Men						
• 18-24	3.6 (2.8 to 4.4)	55.7 (53.6 to 57.8)	25.8 (24.0 to 27.7)	9.5 (8.3 to 10.8)	3.5 (2.8 to 4.3)	1.8 (1.3 to 2.4)
• 25-34	1.2 (0.8 to 1.6)	33.9 (32.1 to 35.6)†	37.6 (35.5 to 39.0)	17.5 (16.1 to 18.9)	6.8 (5.9 to 7.7)†	3.3 (2.7 to 4.0)†
• 35-44	0.5 (0.3 to 0.6)	20.0 (18.9 to 21.1)†	41.4 (40.0 to 42.7)	24.5 (23.3 to 25.7)†	8.6 (7.9 to 9.4)	5.1 (4.5 to 5.7)†
• 45-54	0.4 (0.3 to 0.5)	17.3 (16.6 to 18.1)†	42.1 (41.1 to 43.1)	26.4 (25.5 to 27.3)	9.6 (9.0 to 10.2)†	4.2 (3.8 to 4.6)†
• 55-64	0.3 (0.2 to 0.4)	15.8 (15.1 to 16.5)†	42.0 (41.1 to 42.9)	28.0 (27.1 to 28.8)	9.9 (9.4 to 10.5)†	4.1 (3.7 to 4.4)†
• 65-74	0.2 (0.1 to 0.3)	16.2 (15.4 to 17.0)†	44.7 (43.6 to 45.8)	27.4 (26.4 to 28.4)†	8.5 (7.9 to 9.1)†	3.0 (2.6 to 3.4)
• ≥ 75	0.7 (0.4 to 0.9)	23.6 (22.4 to 24.8)†	47.9 (46.6 to 49.3)	21.2 (20.1 to 22.3)†	5.4 (4.8 to 6.0)†	1.2 (0.9 to 1.5)
• All	0.6 (0.5 to 0.7)	20.7 (20.4 to 21.1)†	42.0 (41.5 to 42.5)	24.8 (24.3 to 25.2)†	8.4 (8.1 to 8.7)†	3.5 (3.4 to 3.7)†
Women						
• 18-24	5.7 (5.1 to 6.3)	58.6 (57.3 to 59.9)†	20.7 (19.6 to 21.7)	8.8 (8.0 to 9.5)	4.1 (3.6 to 4.7)	2.3 (1.9 to 2.7)
• 25-34	2.6 (2.3 to 2.9)	47.9 (46.9 to 48.9)†	25.5 (24.6 to 26.3)	12.5 (11.9 to 13.2)	6.6 (6.1 to 7.1)†	4.9 (4.5 to 5.4)†
• 35-44	1.7 (1.4 to 1.9)	42.6 (41.7 to 43.4)	27.6 (26.8 to 28.4)	14.6 (14.0 to 15.2)	8.0 (7.5 to 8.5)	5.6 (5.2 to 6.0)†
• 45-54	1.2 (1.0 to 1.3)	37.0 (36.3 to 37.8)†	30.9 (30.1 to 31.6)	16.9 (16.3 to 17.5)	8.4 (8.0 to 8.9)†	5.6 (5.2 to 6.0)†
• 55-64	1.0 (0.8 to 1.1)	30.4 (29.6 to 31.1)†	33.0 (32.3 to 33.8)†	19.8 (19.2 to 20.5)	9.9 (9.4 to 10.4)†	5.9 (5.5 to 6.2)†
• 65-74	1.0 (0.8 to 1.2)	27.3 (26.4 to 28.2)†	36.3 (35.4 to 37.3)	21.7 (20.8 to 22.5)	8.9 (8.3 to 9.4)†	4.9 (4.5 to 5.4)†
• ≥ 75	2.1 (1.8 to 2.4)	32.7 (31.6 to 33.8)†	38.0 (36.8 to 39.1)	18.9 (18.0 to 19.8)†	6.1 (5.5 to 6.7)†	2.3 (1.9 to 2.6)
• All	1.8 (1.7 to 1.9)	38.1 (37.7 to 38.4)†	30.6 (30.3 to 31.0)	16.7 (16.4 to 17.0)†	7.9 (9.7 to 8.1)†	5.0 (4.8 to 5.1)†

BMI—body mass index, CCHS—Canadian Community Health Survey, CPCSSN—Canadian Primary Care Sentinel Surveillance Network.
*World Health Organization BMI classes.[16]
†Estimates that are statistically significantly different from the 2011 CCHS results. "Corrected" CCHS estimates were used when comparing CPCSSN estimates with CCHS estimates.

Table 3. Estimates of the percentage of BMI classes in the CPCSSN data sample stratified by age and sex, 2016

AGE GROUP, Y	PREVALENCE ESTIMATE (95% CI), %					
	UNDERWEIGHT* (BMI < 18.5 KG/M²)	NORMAL WEIGHT* (BMI 18.5-24.9 KG/M²)	OVERWEIGHT* (BMI 25-29.9 KG/M²)	OBESE CLASS I* (BMI 30-34.9 KG/M²)	OBESE CLASS II* (BMI 35-39.9 KG/M²)	OBESE CLASS III* (BMI ≥ 40 KG/M²)
Total cohort						
• 18-24	5.2 (4.5 to 5.8)	49.6 (48.1 to 51.2)†	24.8 (23.5 to 26.2)	11.1 (10.1 to 12.1)	5.7 (5.0 to 6.4)	3.5 (3.0 to 4.1)
• 25-34	2.1 (1.7 to 2.4)	37.8 (36.6 to 38.9)†	29.3 (28.2 to 30.4)†	16.7 (15.8 to 17.6)†	8.1 (7.4 to 8.7)	6.1 (5.5 to 6.7)
• 35-44	1.2 (1.0 to 1.5)	29.3 (28.4 to 30.3)†	30.6 (29.6 to 31.6)†	21.4 (20.5 to 22.3)†	10.4 (9.7 to 11.0)	7.1 (6.6 to 7.6)
• 45-54	0.8 (0.7 to 1.0)	24.2 (23.5 to 24.9)†	32.5 (31.7 to 33.3)	23.7 (23.0 to 24.4)†	11.6 (11.1 to 12.2)	7.2 (6.7 to 7.6)
• 55-64	1.0 (0.9 to 1.2)	22.6 (22.0 to 23.2)†	34.7 (34.0 to 35.4)	24.1 (23.5 to 24.7)†	11.1 (10.6 to 11.6)	6.5 (6.2 to 6.9)
• 65-74	0.9 (0.8 to 1.1)	19.4 (18.7 to 20.0)†	36.8 (36.0 to 37.6)†	26.4 (25.6 to 27.1)†	10.8 (10.3 to 11.4)	5.7 (5.3 to 6.1)
• ≥ 75	1.6 (1.4 to 1.9)	26.8 (26.0 to 27.7)†	40.0 (39.1 to 41.0)	21.2 (20.4 to 22.0)†	7.6 (7.1 to 8.1)	2.7 (2.4 to 3.0)
• All	1.4 (1.3 to 1.5)	26.4 (26.1 to 26.8)†	33.9 (33.6 to 34.3)†	22.4 (22.1 to 22.7)†	10.0 (9.8 to 10.2)	5.8 (5.7 to 6.0)
Men						
• 18-24	4.7 (3.6 to 5.8)	47.0 (44.4 to 49.6)†	26.6 (24.3 to 28.9)	12.8 (11.0 to 14.5)†	5.8 (4.6 to 7.0)	3.2 (2.3 to 4.1)
• 25-34	1.6 (1.0 to 2.1)	28.1 (26.0 to 30.2)†	35.8 (33.5 to 38.1)	20.8 (18.9 to 22.7)†	8.4 (7.1 to 9.7)	5.4 (4.3 to 6.5)
• 35-44	0.6 (0.3 to 0.9)	18.0 (16.5 to 19.5)†	37.6 (35.7 to 39.4)	27.1 (25.4 to 28.8)†	10.0 (8.9 to 11.2)	6.8 (5.8 to 7.7)
• 45-54	0.5 (0.3 to 0.7)	14.7 (13.7 to 15.7)†	36.6 (35.3 to 37.9)†	28.8 (27.6 to 30.1)†	12.7 (11.8 to 13.6)	6.7 (6.0 to 7.4)
• 55-64	0.5 (0.3 to 0.6)	15.4 (14.6 to 16.2)†	38.9 (37.8 to 39.9)†	28.4 (27.3 to 29.4)†	11.3 (10.6 to 12.0)	5.7 (5.2 to 6.2)
• 65-74	0.5 (0.4 to 0.7)	13.9 (13.1 to 14.7)†	41.4 (40.2 to 42.5)	29.6 (28.5 to 30.7)†	10.3 (9.6 to 11.0)	4.3 (3.8 to 4.8)
• ≥ 75	0.7 (0.5 to 0.9)	22.7 (21.5 to 24.0)†	44.5 (43.0 to 45.9)	23.3 (22.1 to 24.6)†	6.7 (6.0 to 7.5)	2.1 (1.6 to 2.5)
• All	0.8 (0.7 to 0.9)	18.5 (18.0 to 18.9)†	39.0 (38.4 to 39.5)†	26.7 (26.2 to 27.2)†	10.1 (9.8 to 10.4)	5.0 (4.7 to 5.2)
Women						
• 18-24	5.4 (4.5 to 6.3)	51.2 (49.2 to 53.1)†	23.8 (22.1 to 25.5)	10.2 (9.0 to 11.4)	5.7 (4.8 to 6.6)	3.8 (3.0 to 4.5)
• 25-34	2.2 (1.8 to 2.6)	41.1 (39.7 to 42.5)†	27.1 (25.9 to 28.3)	15.2 (14.3 to 16.2)	8.0 (7.2 to 8.7)	6.3 (5.7 to 7.0)
• 35-44	1.5 (1.2 to 1.8)	34.2 (33.0 to 35.3)†	27.6 (26.5 to 28.7)	19.0 (18.0 to 19.9)†	10.5 (9.8 to 11.3)	7.2 (6.6 to 7.9)
• 45-54	1.1 (0.8 to 1.3)	30.4 (29.4 to 31.4)†	29.8 (28.8 to 30.8)	20.4 (19.5 to 21.3)†	11.0 (10.3 to 11.6)	7.5 (6.9 to 8.0)
• 55-64	1.5 (1.2 to 1.7)	28.4 (27.5 to 29.3)†	31.3 (30.4 to 32.3)†	20.7 (19.9 to 21.5)†	10.9 (10.3 to 11.5)	7.2 (6.7 to 7.7)
• 65-74	1.3 (1.0 to 1.5)	24.4 (23.4 to 25.3)†	32.7 (31.7 to 33.8)	23.4 (22.4 to 24.4)	11.3 (10.6 to 12.0)	6.9 (6.4 to 7.5)
• ≥ 75	2.4 (2.0 to 2.8)	30.1 (28.9 to 31.3)†	36.5 (35.2 to 37.7)	19.5 (18.5 to 20.6)†	8.3 (7.5 to 9.0)	3.2 (2.8 to 3.7)
• All	1.8 (1.7 to 1.9)	31.8 (31.4 to 32.2)†	30.5 (30.1 to 31.0)	19.5 (19.1 to 19.9)†	10.0 (9.7 to 10.3)	6.4 (6.2 to 6.6)

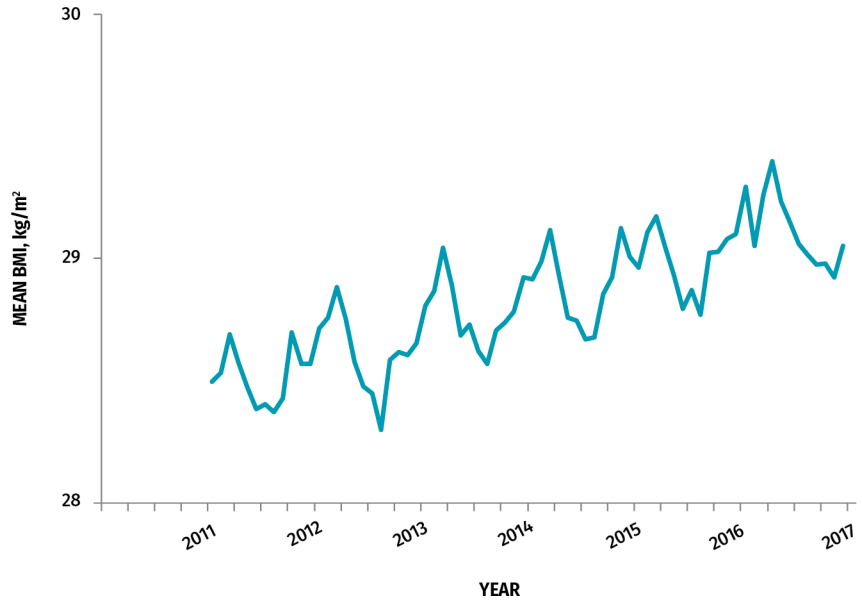
BMI—body mass index, CCHS—Canadian Community Health Survey, CPCSSN—Canadian Primary Care Sentinel Surveillance Network.
*World Health Organization BMI classes.[16]
†Estimates that are statistically significantly different from the 2016 CCHS results. "Corrected" CCHS estimates were used when comparing CPCSSN estimates with CCHS estimates.

the aforementioned observation made using descriptive time-series methods. Sex was an independent predictor of BMI; male participants had BMI values that were on average 1.02 kg/m² higher than those of female participants ($P<.0001$). Average BMI was lowest in the youngest age groups, increasing throughout middle age before decreasing again in the oldest age group. Those in the 55 to 64 age group had BMI values that were on average 2.72 kg/m² higher than those in the youngest age group (ie, 18 to 24 years). Comparing adjacent age categories, the effect of increasing age is most pronounced for those in the younger age groups (eg, 25 to 34 vs 18 to 24 years and 35 to 44 vs 25 to 34 years). The large random intercept variance component suggests that appreciable variation in baseline BMI values is owing to person-level factors (or person-level variation). Most patients follow a similar monotonic linear increasing trend in BMI over time.

Open cohort results

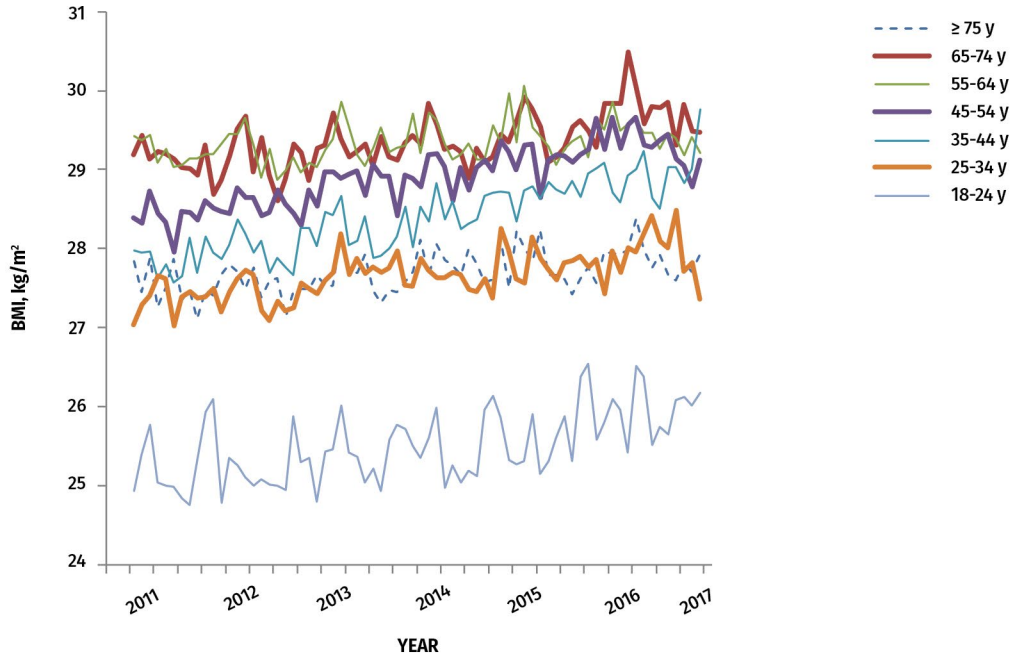
As mentioned before, we performed sensitivity analysis for all inferences derived from the closed cohort sample on the open cohort sample; analyses yielded concordant findings. For this reason, we only present results from the closed cohort analysis.

Figure 2. Time series plot of average BMI for the study period in the whole cohort



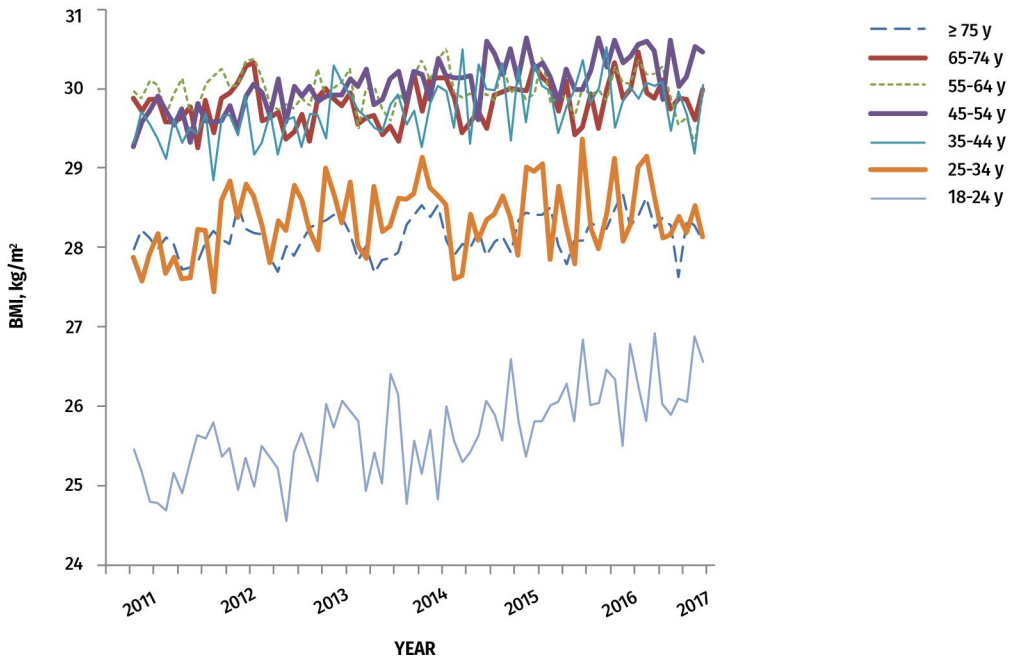
BMI—body mass index.

Figure 3. Time series plot of average BMI for the study period stratified by age categories for female patients



BMI—body mass index.

Figure 4. Time series plot of average BMI for the study period stratified by age categories for male patients



BMI—body mass index.

Discussion

The main finding of this study was that the CPCSSN patients experienced a modest increase in mean BMI by 2.1% from 28.5 kg/m² in 2011 to 29.1 kg/m² in 2016. If we assume the average height in Canada to be 168.7 cm (175.1 cm in men and 162.3 cm in women),[23] by using the BMI formula, this increase can be translated to a 1.7-kg (3.7-lb) increase in body weight over the study period, or to more than half a pound annually. Moreover, BMI tended to increase most rapidly in young adults (age groups 18 to 24 years and 25 to 34 years) compared with older adults. Those in the older age groups tended to have higher BMI values that remained stable at a higher level over time. The average BMI continues to increase with age up to approximately age 75. Beyond this age baseline BMI statistically significantly declines to that comparable with the 25 to 34 age group.

Our finding of an increasing trend in BMI in the CPCSSN population over time is consistent with a previous study[15] that used data from CPCSSN between 2003 and 2012. Rigobon et al[15] showed that the estimated prevalence of obesity increased from 17.9% in 2003 to 30.8% in 2012, while the estimated prevalence of obesity in the present study increased from 32.2% in 2011 to 38.2% in 2016. Although estimates vary, a number of cross-sectional surveys have found an increasing prevalence of obesity in Canada.[24-26] Data from the 2007-2009, 2009-2011, and 2012-2013 cycles of CHMS have shown

Table 4. Fitted autoregressive linear mixed-effects model of BMI (kg/m²) as a function of baseline age, sex, and centred time: *The intercept term in the following model corresponds to the expected BMI value for a female patient, aged 18-24 y, measured in the middle of the study (approximately January 1, 2014). Random intercept variance was 31.35, residual variance was 4.12, and the AR1 working correlation parameter was 0.41.*

VARIABLES	β	SE	*P* VALUE
Intercept (constant)	25.68	0.03	< .0001
Male sex	1.02	0.02	< .0001
Age* groups, y			
• 18-24	Reference	-	-
• 25-34	1.28	0.03	< .0001
• 35-44	2.12	0.03	< .0001
• 45-54	2.60	0.03	< .0001
• 55-64	2.72	0.03	< .0001
• 65-74	2.59	0.03	< .0001
• ≥ 75	2.06	0.04	< .0001
Centred time, y	0.06	0.002	< .0001

AR1—first-order autoregression, β—regression coefficient, BMI—body mass index, SE—standard error.
*Age calculated from birth date to January 1, 2011 (study baseline).

that the prevalence of obesity among adults ranged from 23.9% to 26.4%,[9] so the primary care data are highly consistent with general trends. More worrying is that the Canadian data reflect global trends. A pooled analysis of 1698 population-based measurement studies with 19.2 million participants between 1975 and 2014 reported that global age-standardized mean (95% credible interval) BMI increased from 21.7 (21.3 to 22.1) kg/m^2 to 24.2 (24.0 to 24.4) kg/m^2 in men, and from 22.1 (21.7 to 22.5) kg/m^2 to 24.4 (24.2 to 24.6) kg/m^2 in women within 4 decades.[27] Similar findings were reported in a meta-analysis by Ng et al.[28] Urgent global attention to obesity is needed, as there are no reported national success stories in shifting overall trends in the past 33 years.[28] Given this global obesity epidemic, what are the responsibilities of Canadian family physicians and where would scarce resources be best directed?

According to the most recent meta-analysis by the US Preventive Services Task Force,[29] weight reduction interventions for those who are obese and overweight have modest effects (about 2.4 kg) on weight, but randomized trial evidence is robust on the potential to decrease the incidence of type 2 diabetes in at-risk groups, as recommended by the 2015 Canadian Task Force on Preventive Health Care guidelines.[7] In addition, data on important subgroups, as well as data on long-term weight and health outcomes, are limited.[29] Therefore, it is crucial that primary care target prevention strategies for health risks associated with weight gain and diabetes. To provide focused initiatives, it is necessary to identify critical age groups at risk of weight gain. In this large cohort of patients attending primary care, our results suggest that the critical age for weight gain is in the younger age groups (25 to 34 years and 35 to 44 years), and there is little change in BMI for individuals beyond age 45 years. Excessive weight gained during early adulthood is linked to a greater risk of chronic diseases and complications, such as type 2 diabetes and premature death later in life.[30] Therefore, to reverse these trends young adults should be the focus of targeted prevention and intervention research efforts. It is noteworthy that the examination of trends in prevalence of excess weight in children and youth from primary care EMRs was beyond the scope of this study, although this age group may present an even more upstream and potentially optimal subgroup for intervention, particularly for very young children in whom early intervention could possibly have the greatest positive health effect.[31,32]

Limitations

There are potential limitations to this study that need to be mentioned. First, there is the possibility of a systematic bias toward overestimating BMI in our data because primary care users represent a (non-random) sample of the population, who may have more chronic conditions and poorer health than the general population.[33] Second, a shortcoming of the CPCSSN database is that BMI data can be incomplete. Measurements of BMI are more likely to be recorded when the patient is attending with a health-related concern such as weight, fitness, or a medical problem, and there is the possibility of a systematic bias toward overestimation of BMI in patients with a recorded BMI measurement compared with patients without a recorded BMI measurement. It has been previously suggested that BMI completeness within the CPCSSN database increased from 17.7% in 2003 to 43.5% in 2011, and that later BMI data are more reliable.[15] The time frame of interest for this study was narrowed down to the more recent years from 2011 through 2016 to address this bias. Third, although we used recent data from 2011 to 2016, this CPCSSN sample is still much more likely to comprise female and older patients and therefore cannot be considered representative of the general population.[15,33] Finally, we were unable to control for comorbidities such as hyperlipidemia, cardiovascular disease, hypertension, and type 2 diabetes mellitus, or any medication use (particularly medications used as clinical interventions to optimize BMI), as well as for any obesity services, physical activity level, or pregnancy status that could have affected BMI measurements of our studied patients.

Conclusion

Our findings confirm a continuing rise in the weight (1.7 kg [3.7 lb]) per average height of the CPCSSN population from 2011 to 2016. Body mass index tended to increase most rapidly in young adults (age groups of 18 to 24 years and 25 to 34 years) compared with older adults. These findings support focusing prevention initiatives on younger age groups for both sexes, as this could be a critical time period when accelerated weight gain is occurring. It is unclear to what extent current services in the primary care setting may be having an effect on body weight. Much more work is needed to determine the best evidence-based practices for management of obesity in this setting.

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Contributors
All authors contributed to the concept and design of the study; data gathering, analysis, and interpretation; and preparing the manuscript for submission.

Competing interests
None declared

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