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QUANTITATIVE RESEARCH

Updating normative cross-sectional values and secular trends in body mass, body height and body mass index among Québec children and adolescents

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Abstract

Objective The main objective of this study was to examine secular trends in body mass, body height and body mass index (BMI) from measured rather than self-reported values between 1972 and 2017.

Methods A total of 4500 students (males = 51%) were selected from a stratified sampling. The age range varied between 6.0 and 17.9 years. The sample came from 24 elementary schools and 12 high schools located in six urban cities from the province of Québec. All the tests selected were based on standardized procedures that are recognized as valid and reliable. Standardization and modeling of smoothed percentile curves for each variable for both sexes were produced.

Results Regional variations between youth from the province of Québec and those from all other Canadian provinces confirm the relevance of using data specific to the target population. Comparisons with the 1972 and 1982 data show an important increase in body mass (~7 kg, i.e. 16.4%) and BMI (~1.4 kg·m^{-2}, i.e. 19.9%) with minor change in body height (~1.8 cm, i.e. 3.9%). Youth from low-income backgrounds ($p = 0.001$) as well as those living in large urban cities ($p = 0.002$) see their probability of developing overweight or obesity greatly increase (low-income = 2.1 times; large urban cities = 1.3 times). However, overweight and obesity rates seem to have stabilized at around 21% since 2004.

Conclusion This study provides up-to-date data on factors that contribute to the prevalence of overweight and obesity in youth in urban settings of Québec, and will be instrumental in guiding public health strategies designed to optimize growth outcomes.

Résumé

Objectif L'objectif principal de cette étude était d'examiner les tendances séculaires de la masse corporelle, de la taille et de l'indice de masse corporelle (IMC) de 1972 à 2017 à partir de valeurs mesurées plutôt que de valeurs autodéclarées.

Méthode Un total de 4 500 étudiants (garçons = 51 %) ont été sélectionnés à partir d'un échantillon stratifié. La fourchette d'âge variait entre 6,0 et 17,9 ans. L'échantillon provenait de 24 écoles primaires et 12 écoles secondaires situées dans six villes de la province de Québec (Canada). Tous les tests sélectionnés reposaient sur des procédures standardisées, reconnues comme valides et fidèles. Une standardisation et une modélisation des courbes centiles lissées ont été produites pour chaque variable pour les deux sexes.

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Résultats Les variations régionales entre les jeunes du Québec et ceux du reste du Canada confirment la pertinence d'utiliser des données spécifiques à la population cible. Les comparaisons entre les données de 1972 et de 1982 montrent une augmentation importante de la masse corporelle et de l'IMC ($p \leq 0{,}05$) sans changement important de la taille corporelle. Les jeunes issus de milieux à faibles revenus ($p = 0{,}001$) ainsi que ceux vivant dans les grandes villes ($p = 0{,}002$) voient leurs risques de développer un surpoids ou de l'obésité augmenter considérablement (faibles revenus = 2,1 fois; grandes villes urbaines = 1,3 fois). Toutefois, les taux de surpoids et d'obésité semblent s'être stabilisés autour de 21 % depuis 2004.
Conclusion Cette étude fournit des données à jour sur les facteurs qui contribuent à la prévalence de l'embonpoint et de l'obésité chez les jeunes des milieux urbains du Québec et contribuera à orienter les stratégies de santé publique afin d'optimiser le suivi sur la croissance physique des jeunes.

Keywords Youth · Anthropometry · Secular trends · Overweight/obesity · Cross-sectional study

Mots-clés Jeunes · anthropométrie · tendances séculaires · surpoids/obésité · étude transversale

Introduction

It is widely accepted that excess of body mass and stunted body height growth during childhood and adolescence are good predictors of current and future health outcomes (Albertsson-Wikland et al., 2021; Esquivel-Lauzurique et al., 2019; Spencer et al., 2018). Due to various biological and socio-demographic changes, physical growth outcome may show undesirable status over time. For example, Health Canada (2016) reports that the prevalence of obesity in Canadian youth has more than tripled over the last 30 years. This observation is of concern given the immediate and future public health issues that may result from this situation. In such circumstances, it appears important to ensure that a regular update of normative growth data references is available in order to be able to ensure effective surveillance. However, in order to optimize the accuracy of such information, several factors must be considered.

Measured versus self-reported values

One important issue concerns the way in which the data are collected. For practical reasons, it is common that body mass and body height data are collected via questionnaires where the values are self-reported. Nonetheless, it is known that self-reported anthropometric measures exhibit several biases. In adults and adolescents of both sexes, there is a significant overestimation of body height and underestimation of body mass (Shields et al., 2011). It is therefore strongly suggested, whenever possible, to opt for measured values (Roberts et al., 2012; Sherry et al., 2007). In Canada, studies including direct measurements in children and adolescents are rare and often include significant methodological differences (Canada Fitness Survey, 1983; Roberts et al., 2012; Statistics Canada, 2017) which complicate comparisons between studies and their insertion in a secular trend analysis particularly restricted to Québec population.

Regional variations

In a recent report for Europe, the World Health Organization (WHO, 2022) indicates significant regional disparities in overweight/obesity between countries with rates ranging from 15.3% in Kyrgyzstan to as high as 35.3% in Greece in youth aged 10 to 19. Even within the same country, regional differences can be observed. In Canada, disparities in the prevalence of obesity between provinces may vary from 12.8% in British Columbia to 25.4% in Newfoundland (Public Health Agency of Canada, 2011). With such variations, it appears relevant, where possible, to develop specific reference standards for the population of interest.

Two large-scale studies were particularly interested in the distinct character of Québec youth in terms of body mass and body height. The first was conducted by Demirjian and his team in 1972. The most recent is that of Léger and Lambert in 1983. As reported by Léger and Lambert (1983), significant anthropometric differences have been noted between adolescents from Québec and those from the rest of Canada, the former being generally shorter and lighter. Thus, the use of Canadian data with the population of Québec may cause clinical interpretation bias.

Socioeconomic status

Canadian children and adolescents aged 5 to 17 from low-income families are more likely to develop obesity (Phipps et al., 2006; Rao et al., 2016). According to Statistics Canada, the prevalence of overweight among children living in very low-income environments was 23.9% against 16.8% for youth from high-income families, while for obesity, values are 16.9% against 9.3% respectively (Rao et al., 2016). It does seem important to look at the impact of socioeconomic status (SES) on the body composition of Québec youth.

Large versus small urban centres

According to Mitura and Bollman (2004), Canadian teenagers living in small urban centres are more likely to be overweight or obese than those living in large urban centres (males = 34.0% versus 27.4%; females = 20.1% versus 17.4% respectively). Living in small urban areas seems to affect males more specifically. It should be noted, however, that these data are nearly 20 years old and do not reflect regional (provincial) variations.

Therefore, considering the current situation, the primary purpose of this study is to update data on the physical growth for youth from the Québec population since the most recent measured values date back about 50 years. The second objective is to measure the secular trends of body mass, body height and body mass index (BMI). The final objective is to provide an updated portrait according to the specific sociodemographic characteristics of youth from the Québec population.

Methods

Design

This study is a descriptive comparative research with a cross-sectional design based on a large sample of children and adolescents from Canada (Québec).

Participants

A total of 4500 students (males = 51%) participated in this study between 2014 and 2017. The age range varied between 6.0 and 17.9 years, which covers elementary and high school education in Canada. The sample was selected from a total of 36 different schools (elementary school $N = 24$ and high school $N = 12$) located in six cities (Montréal, Québec City, Saguenay, Trois-Rivières, Laval and Sherbrooke). A team of qualified trainees who attended a 45-h training made anthropometric measures. Parents and students were informed of the project and could indicate their willingness to participate or not (a consent form was signed by the school authorities). The Institutional Ethical Committee Board of the University of Québec in Chicoutimi approved the project (no: 602-225-01).

Selection of the school boards, schools and classrooms

It was determined that a three-stage sampling approach would be appropriate for the selection of a representative number of school boards, schools and classrooms (Kalton & Anderson, 1986). Each school received an invitation letter in order to take part in the project. Over 300 schools expressed their interest to participate in this project. Thus, the regions of Montréal, Laval and Québec City allow reasonable sampling relative to the large urban area (> 400,000 inhabitants), and Saguenay, Sherbrooke and Trois-Rivières as small urban areas (100,000 to 200,000 inhabitants), according to the classification suggested by Mitura and Bollman (2004).

Particular attention was also paid to the equitable representation of the various socioeconomic groups in our sample. Each school receives a rating from the Québec government based on its SES (Ministère de l'Éducation et de l'Enseignement Supérieur, 2017). A school's SES refers to the proportion of families with children whose income is near or below the low-income cut-off. The ranking is constructed on a discrete scale ranging from 1 to 10 where 1 represents a high-income SES and 10 a very low-income status. Therefore, schools ranked 1 to 5 were considered high-income and 6 to 10 low-income.

All schools and classrooms were randomly selected by lot. Apart from very rare exceptions, all students of the same class were assessed, thus eliminating selection bias. If a chosen school withdrew, a new draw was then carried out. The sample size required to perform this study ($N = 3212$ participants) was determined by a Cohen's d power analysis in order to detect medium effects ($d < 0.5$) with a $1\text{-}\beta = 0.95$ for $\alpha = 0.05$ using G Power software version 3.1.9.4.

Anthropometric measures

All the tests selected were based on standardized procedures that are recognized as valid and reliable. Anthropometric variables (body mass (BM), body height (BH) and BMI) were collected during physical education classes, one student at a time, out of sight, using procedures suggested by Lohman et al. (1988). In a room adjacent to the gymnasium, kinesiology interns performed anthropometric measurements away from other participants. BM was noted to the nearest 0.1 kg using a Detecto scale (Missouri, USA). BH was assessed using a SECA model 213 stadiometer (Hamburg, Germany) to the nearest 0.1 cm. BMI was calculated using the following formula: $BM \cdot BH^{-2}$. BMI (normal vs overweight and obesity) was classified as suggested by Cole et al. (2000).

Data exclusions

As suggested by the WHO (2006), participants with "unhealthy" weight-for-height (less than the 0.135th percentile or greater than the 97.7th percentile) were excluded prior to curve smoothing. Thus, 316 individuals (7.0%) were excluded using this criterion (outliers included). Inclusion of these data (especially for individuals above the 97.7th percentile, which are much more numerous) would have resulted in an underclassification of overweight, as the threshold criteria based on weight and BMI for age percentiles would have been shifted upward.

Statistical analysis

All descriptive values are reported as mean ± standard deviation (SD). Confidence intervals (CI) were set at the 95% level. Cohen's effect sizes were calculated for various intergroup comparisons. Odds ratios were compiled using binary logistic regression to predict the probability of being overweight or obese, according to SES and size of city of residence. The Shapiro–Wilk test for normality was compiled for each variable. When normality was transgressed, a Box-Cox transformation was conducted using the following equation (Box & Cox, 1964):

$$BC = (VAR^{L} - 1) \cdot L^{-1} \text{ when } L \neq 0$$

$$BC = \text{Log}\,(VAR) \text{ when } L = 0$$

where BC = Box-Cox transformation, VAR = variable, and L = Lambda.

The Box-Cox power exponential method, which smoothed the curves by cubic splines, has been used to create the curves (WHO, 2006).

Table 1 Normalized anthropometric profiles of males and females 6.0–17.9 years of age

Age (years)	Body mass (kg)		Body height (cm)		BMI (kg·m^{-2})	
	Mean ± SD	CI (95%)	Mean ± SD	CI (95%)	Mean ± SD	CI (95%)
Males						
6.0–6.9	22.4 ± 3.2	21.7–23.0	119.9 ± 4.8	118.9–121.0	15.6 ± 1.5	15.3–16.0
7.0–7.9	25.0 ± 3.9	24.4–25.6	125.2 ± 5.4	124.4–126.0	15.8 ± 1.8	15.5–16.1
8.0–8.9	27.6 ± 4.2	27.0–28.1	131.1 ± 6.0	130.3–131.9	16.0 ± 1.6	15.8–16.2
9.0–9.9	30.6 ± 5.2	29.9–31.3	136.0 ± 6.4	135.1–136.9	16.3 ± 2.1	16.1–16.6
10.0–10.9	35.0 ± 6.5	34.1–35.9	141.9 ± 6.2	141.1–142.7	17.1 ± 2.3	16.8–17.4
11.0–11.9	39.3 ± 7.3	38.2–40.4	148.2 ± 7.1	147.2–149.2	18.0 ± 2.5	17.6–18.4
12.0–12.9	45.7 ± 9.3	44.5–46.9	153.8 ± 8.2	152.8–154.8	19.2 ± 2.9	18.9–19.6
13.0–13.9	53.0 ± 11.7	51.5–54.4	160.9 ± 9.0	159.8–162.1	20.3 ± 3.4	19.8–20.7
14.0–14.9	57.9 ± 10.1	56.4–59.4	166.0 ± 7.5	164.9–167.1	21.0 ± 3.3	20.5–21.5
15.0–15.9	62.6 ± 11.2	61.1–64.2	170.4 ± 6.5	169.6–171.3	21.5 ± 3.5	21.1–22.0
16.0–16.9	66.2 ± 11.2	64.6–67.8	173.4 ± 6.6	172.4–174.4	22.1 ± 3.5	21.6–22.6
17.0–17.9	68.8 ± 11.7	66.4–71.1	173.8 ± 7.8	172.2–175.3	22.7 ± 3.2	22.0–23.3
Females						
6.0–6.9	21.6 ± 3.5	20.9–22.3	119.0 ± 5.8	117.9–120.1	15.2 ± 1.7	14.8–15.5
7.0–7.9	23.8 ± 3.4	23.3–24.4	124.7 ± 5.5	123.9–125.5	15.4 ± 1.7	15.1–15.6
8.0–8.9	27.3 ± 4.4	26.6–27.9	130.8 ± 6.1	130.0–131.7	15.9 ± 2.0	15.6–16.2
9.0–9.9	30.7 ± 5.6	30.0–31.5	135.9 ± 6.5	135.1–136.8	16.6 ± 2.1	16.3–16.9
10.0–10.9	36.2 ± 7.7	35.2–37.3	143.8 ± 7.7	142.8–144.8	17.4 ± 2.7	17.0–17.8
11.0–11.9	41.7 ± 8.4	40.6–42.8	150.9 ± 7.5	150.0–151.9	18.2 ± 2.8	17.9–18.6
12.0–12.9	47.5 ± 9.5	46.3–48.6	154.7 ± 6.3	154.0–155.5	19.9 ± 3.4	19.5–20.3
13.0–13.9	52.0 ± 10.7	50.6–53.4	157.7 ± 5.9	156.9–158.5	21.0 ± 3.7	20.5–21.5
14.0–14.9	54.9 ± 10.0	53.3–56.5	158.0 ± 6.3	157.1–159.0	22.0 ± 3.7	21.4–22.6
15.0–15.9	56.4 ± 8.7	54.9–58.0	161.0 ± 6.3	159.9–162.1	21.8 ± 2.9	21.3–22.4
16.0–16.9	59.0 ± 9.4	57.5–60.6	163.2 ± 7.2	162.0–164.4	22.3 ± 2.8	21.8–22.8
17.0–17.9	59.2 ± 9.6	57.0–61.3	163.2 ± 7.5	161.6–164.8	22.1 ± 3.2	21.4–22.8

SD Standard deviation, *CI* Confidence interval

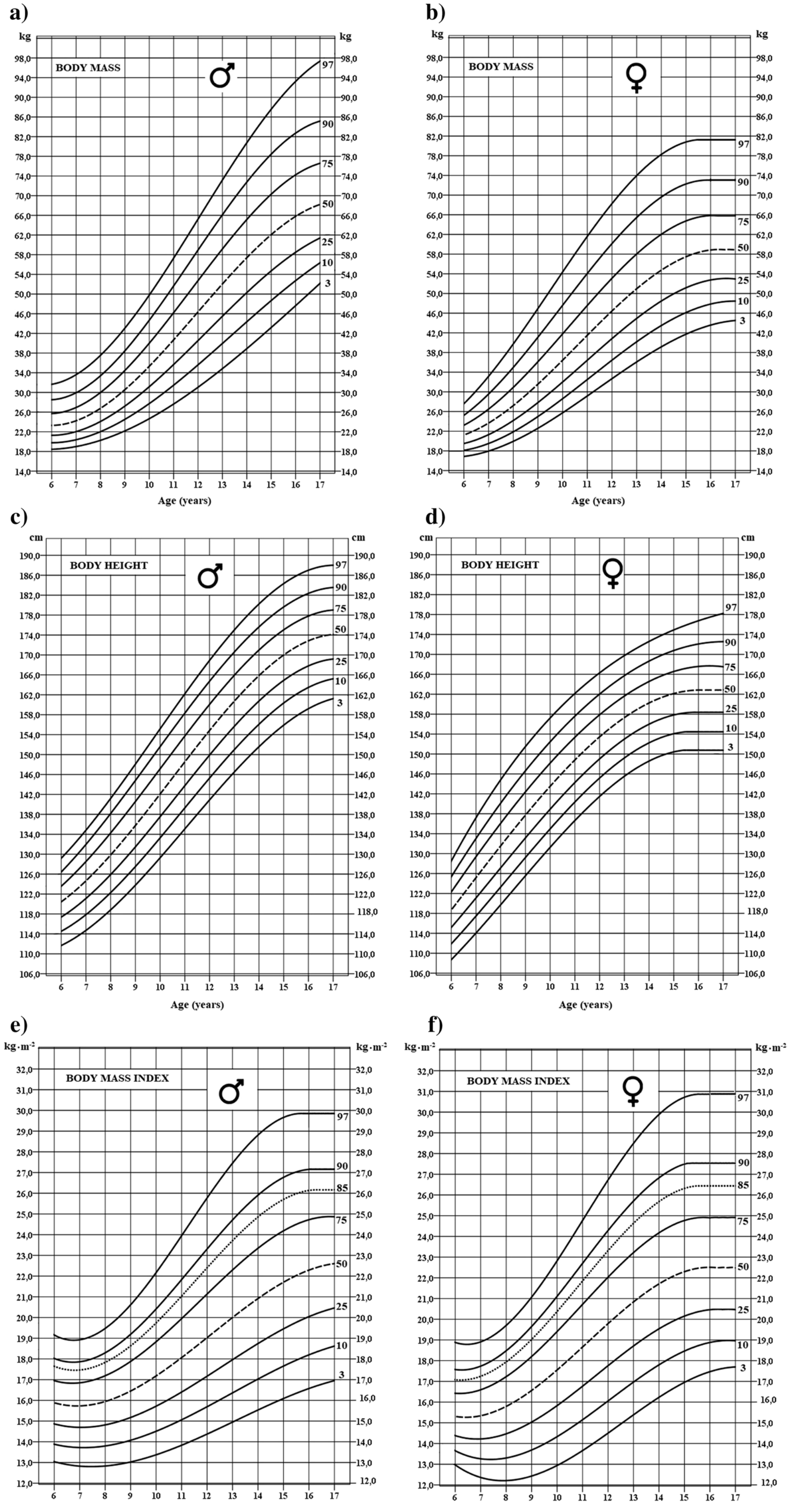

Fig. 1 Age-specific smoothed percentile curves for body mass, body height and body mass index for males (**A**, **C** and **E**) and females respectively (**B**, **D** and **F**)

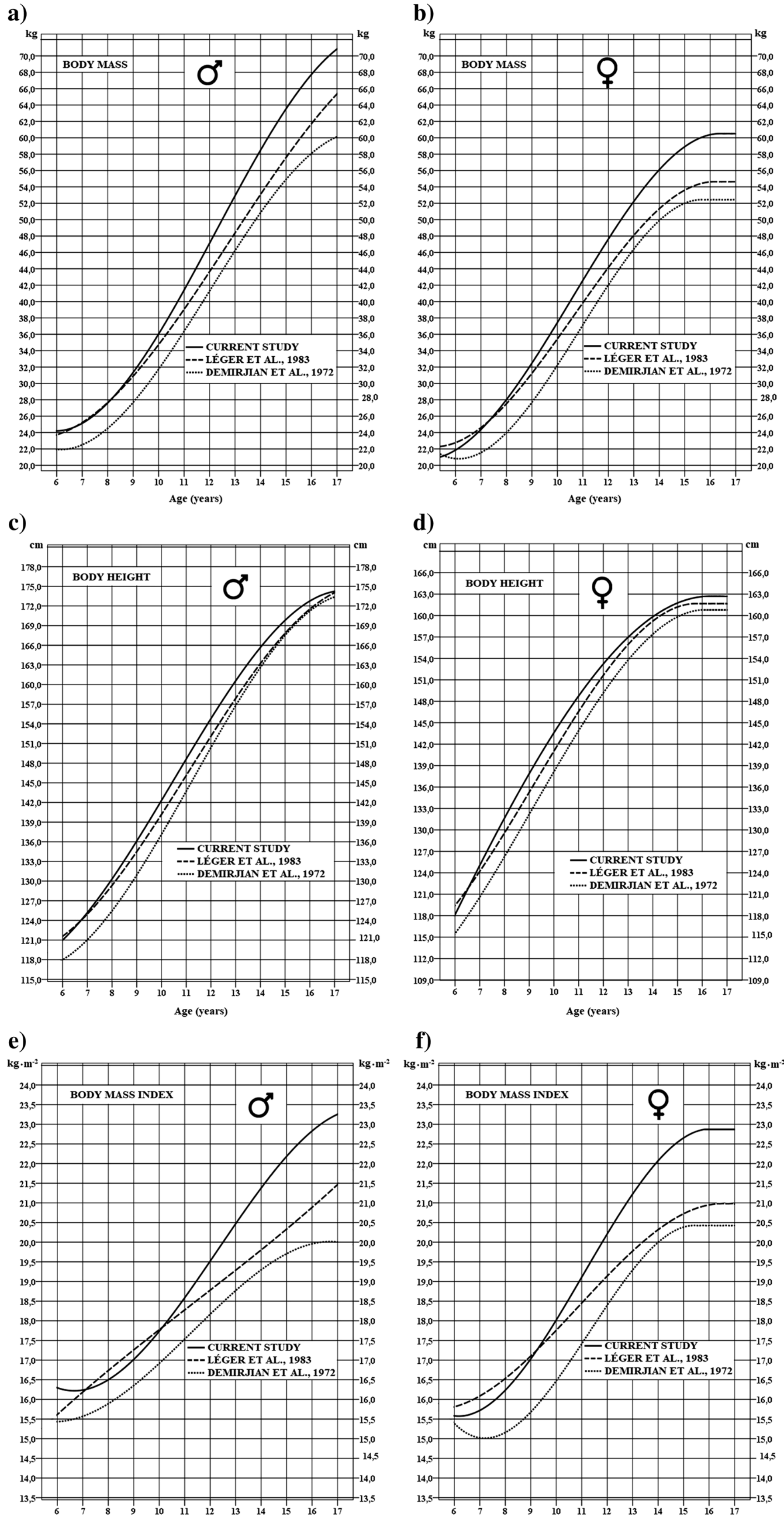

Fig. 2 Modeling of secular trend curves for body mass, body height and body mass index in 1972, 1982 and 2017 for males (**A**, **C** and **E**) and females (**B**, **D** and **F**)

Table 2 Secular trends for body mass and body height between 1982 and 2017 in children and adolescents from the province of Québec

	Current study			Léger and Lambert (1983)			Statistics			
Age (years)	*N*	Body mass (kg)	Body height (cm)	*N*	Body mass (kg)	Body height (cm)	*P* values Body mass	*P* values Body height	Cohen's d ES Body mass	Cohen's d ES Body height
Males										
6	96	23.6 ± 6.1	120.4 ± 5.8	89	23.4 ± 3.0	121.4 ± 5.5	0.780	0.231	0.04	0.17
7	166	25.7 ± 6.0	125.5 ± 5.8	221	25.2 ± 4.3	124.6 ± 6.3	0.524	0.151	0.10	0.15
8	227	28.5 ± 6.8	131.2 ± 6.5	211	28.0 ± 4.5	130.1 ± 5.8	0.555	0.063	0.09	0.18
9	209	31.3 ± 8.2	136.5 ± 7.2	200	31.8 ± 5.7	134.8 ± 6.4	0.701	**0.012**	0.07	0.25
10	233	35.2 ± 7.8	141.8 ± 6.6	253	34.6 ± 5.9	140.4 ± 6.3	0.337	**0.017**	0.09	0.22
11	189	40.7 ± 10.1	148.2 ± 7.4	247	38.8 ± 7.8	145.9 ± 7.1	**0.027**	**0.001**	0.21	0.32
12	244	47.0 ± 12.6	153.8 ± 8.6	206	42.7 ± 7.9	151.0 ± 8.4	**0.000**	**0.001**	0.40	0.33
13	248	54.0 ± 13.2	160.8 ± 9.1	233	47.8 ± 8.6	158.0 ± 8.6	**0.000**	**0.000**	0.55	0.32
14	188	58.5 ± 12.7	166.2 ± 8.0	237	53.4 ± 9.8	163.0 ± 8.5	**0.000**	**0.000**	0.46	0.39
15	214	63.6 ± 13.4	170.3 ± 6.7	254	58.3 ± 9.7	168.2 ± 7.5	**0.000**	**0.002**	0.46	0.29
16	188	67.4 ± 15.1	172.9 ± 7.5	245	62.6 ± 9.2	172.8 ± 7.4	**0.000**	0.890	0.40	0.01
17	104	70.9 ± 15.8	173.8 ± 7.8	161	64.5 ± 8.9	173.1 ± 6.7	**0.000**	0.437	0.53	0.10
Females										
6	109	21.8 ± 4.4	119.0 ± 6.2	81	22.8 ± 2.9	120.0 ± 5.0	0.077	0.235	0.26	0.18
7	182	24.6 ± 4.8	124.8 ± 5.7	227	24.4 ± 3.6	123.9 ± 6.1	0.631	0.128	0.05	0.15
8	214	28.7 ± 7.4	130.7 ± 6.2	231	28.0 ± 5.2	129.3 ± 6.7	0.246	**0.023**	0.11	0.22
9	229	31.3 ± 7.2	136.1 ± 6.9	196	31.4 ± 5.6	134.3 ± 6.9	0.875	**0.008**	0.02	0.26
10	223	36.9 ± 9.1	143.8 ± 8.3	214	34.6 ± 7.0	140.7 ± 7.1	**0.003**	**0.000**	0.26	0.40
11	233	42.4 ± 9.8	150.9 ± 8.0	258	39.2 ± 8.5	147.3 ± 7.9	**0.000**	**0.000**	0.35	0.45
12	275	48.8 ± 12.4	154.7 ± 6.9	204	45.1 ± 9.0	153.1 ± 7.8	**0.000**	**0.018**	0.33	0.22
13	220	52.9 ± 12.7	157.4 ± 6.8	224	49.2 ± 9.0	156.9 ± 6.9	**0.000**	0.442	0.34	0.07
14	159	57.0 ± 13.8	157.8 ± 6.5	211	50.4 ± 7.3	157.7 ± 5.9	**0.000**	0.877	0.62	0.02
15	123	56.7 ± 9.7	161.0 ± 7.1	189	53.6 ± 7.1	161.0 ± 6.4	**0.001**	1.000	0.38	0.00
16	150	60.3 ± 12.3	162.5 ± 8.9	236	54.2 ± 7.8	160.5 ± 6.3	**0.000**	**0.010**	0.62	0.27
17	89	60.8 ± 13.3	163.2 ± 8.2	133	54.4 ± 7.4	161.2 ± 5.7	**0.000**	**0.033**	0.63	0.29

N Number of participants, *P values in bold* significant at ≤ 0.05, *ES* Effect size

Outliers were identified using the method proposed by Hoaglin and Iglewicz (1987). The equation reads as follows:

$$((Q75 - Q25) \cdot g) - Q25 \text{ for the lowest value}$$

$$((Q75 - Q25) \cdot g) + Q75 \text{ for the highest value}$$

where Q75 = 3rd quartile, Q25 = 1st quartile, and g = 2.2.

Percentiles values were computed using the LMS method, which reads as follows (Cole & Green, 1992):

$$P = M \cdot [1 + LSZ]^{1/L}$$

where P = Percentile, M = Median, L = Lambda, S = Coefficient of variation, and Z = Z-score for the desired percentile.

In order to be able to assess changes that have occurred between 1982 and 2017, the data from the present study were compared with the study carried out by Léger and Lambert in 1983, using an independent t-test. Statistical analysis was performed using the IBM-SPSS software version 24.

Results

Table 1 shows anthropometric characteristics according to age and sex. From the age of 10, females are heavier and taller than males until about 13 years of age, which corresponds to the puberty of females. However, the pattern of BMI presents a different picture where males and females show a similar progression throughout the physical growth period.

The modeling of the smoothed percentile curves for BM, BH and BMI for both sexes is presented in Fig. 1. The 50th percentile represents the median value for each of the variables. It is generally noted that the graph curves for females (Fig. 1B, D, F) tend to level off from the age of 15, which is not the case for males (Fig. 1A, C, E). The parameters and values used to

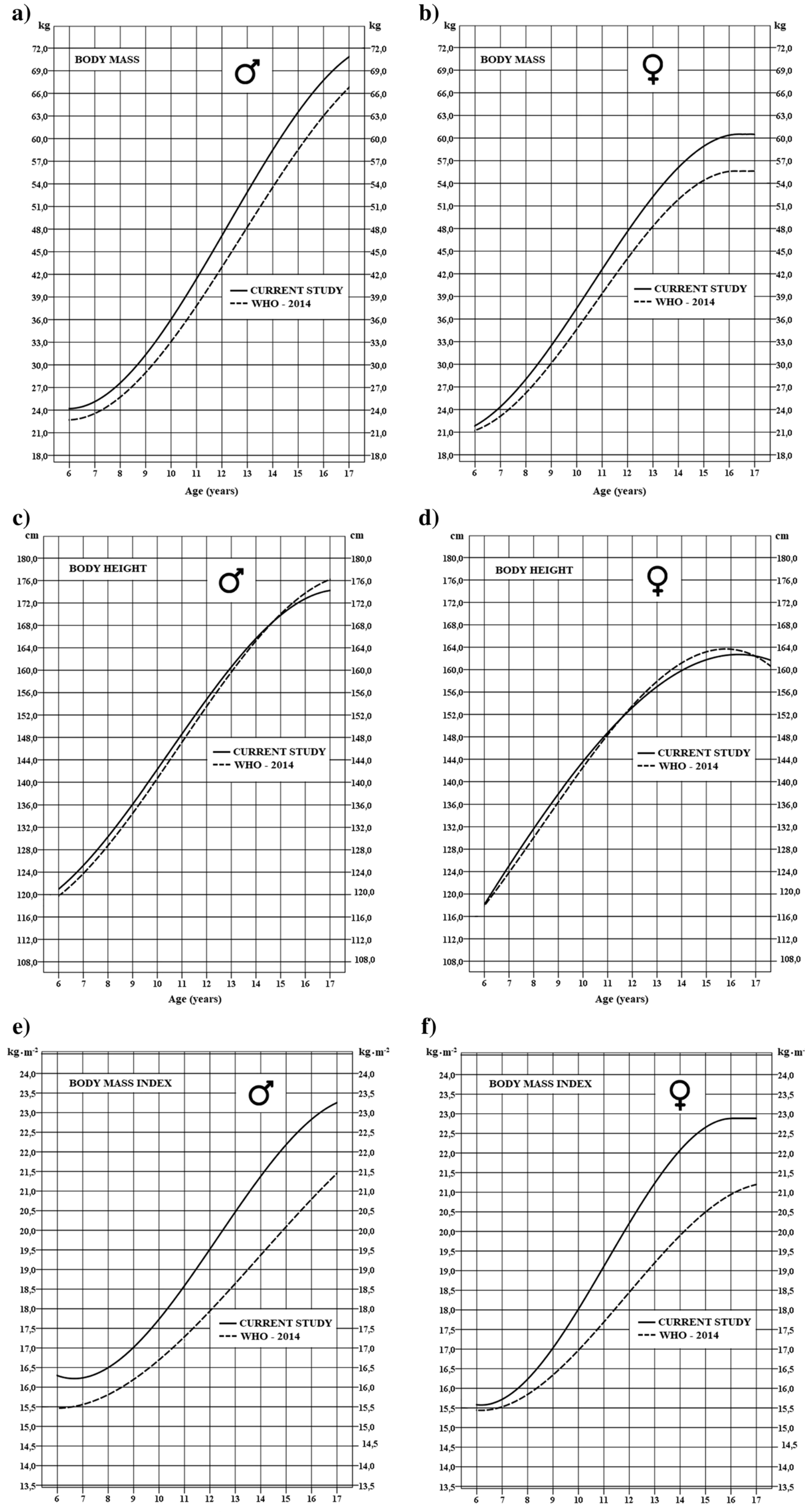

Fig. 3 Comparison of age-specific differences in body mass, body height and body mass index between the present study and the WHO curves for Canadian males (**A**, **C** and **E**) and females (**B**, **D** and **F**)

Table 3 The effects of the SES and locality (large versus small urban areas) on the prevalence of overweight/obesity in children and adolescents from the province of Québec

	N	Typical BMI	*N*	Over-weight/ Obese	Odds ratio	Confidence interval	*P* values (Pearson χ)
Males 6–11 years							
High-income	723	90.8%	73	9.2%	1.7	1.1–2.7	0.018
Low-income	186	85.3%	32	14.7%			
Large urban	626	88.0%	85	12.0%	1.9	1.2–3.2	0.009
Small urban	297	93.4%	21	6.6%			
Males 12–17 years							
High-income	304	76.2%	95	23.8%	1.4	1.1–1.9	0.009
Low-income	499	70.8%	206	29.2%			
Large urban	333	67.0%	164	33.0%	1.7	1.3–2.2	0.000
Small urban	470	77.4%	137	22.6%			
Females 6–11 years							
High-income	737	87.4%	106	12.6%	1.1	0.7–1.7	0.615
Low-income	206	86.2%	33	13.8%			
Large urban	651	85.3%	112	14.7%	1.8	1.2–2.8	0.006
Small urban	313	91.3%	30	8.7%			
Females 12–17 years							
High-income	240	79.2%	63	20.8%	1.7	1.2–2.4	0.001
Low-income	443	69.1%	198	30.9%			
Large urban	303	67.2%	148	32.8%	1.6	1.2–2.2	0.001
Small urban	380	77.1%	113	22.9%			
All (males and females)							
High-income	2004	85.6%	337	14.4%	2.1	1.8–2.4	0.000
Low-income	1334	74.0%	469	26.0%			
Large urban	1913	79.0%	509	21.0%	1.3	1.1–1.5	0.002
Small urban	1460	82.9%	301	17.1%			

χ Chi square, *Odds ratio* The proportion (odds) of youth from low-income families and/or large urban areas to develop overweight or obesity

generate the graph curves are detailed in Supplementary materials (Table 5 for BM, Table 6 for BH and Table 7 for BMI).

Figure 2 shows the secular trends for BM, BH and BMI across different time intervals from three different studies. The three studies (Demirjian et al., 1972; Léger and Lambert, 1983 and the present study 2017) collected data in the province of Québec. However, Demirjian's study is restricted to the Montreal area, while the other two cover several regions of the province of Québec. Thus, Fig. 2A and 2B (males and females respectively) show that participants in the current study are heavier across most of the age range compared to the other two studies. Figure 2C (males) and 2D (females) highlight variations in BH over the past 50 years. Although the youth in this study appear taller during most of the growth period, we note that at the age of 17, this difference in males disappears. Finally, the BMI values in the current study show a significant secular increase in both males (Fig. 2E) and females (Fig. 2F). Due to the numerous similarities between the Léger and Lambert study and the current study (same cities, same school boards, same school setup, same type of equipment, etc.), Table 2 provides a detailed comparison of trends in youth BM and BH growth since 1982.

Since most clinicians in Québec use the Canadian standards produced by the WHO (2014), Fig. 3 compares BM, BH and BMI between the two studies. The BM of males and females in our study is higher than the Canadian reference values throughout the age groups (Fig. 3A and 3B for males and females respectively). However, the evolution of BH shows a different pattern. Indeed, we note that the curves for BH indicate a slight advantage for youth in this study until the onset of puberty, both for males (Fig. 3C) and for females (Fig. 3D). Subsequently, the curves tend to reverse, indicating lower BH values at age 17 in youth from the Québec population. Large differences in BM coupled with small variations in BH have a significant impact on BMI. As illustrated by Fig. 3E and 3F, the differences in BMI increase considerably with age between the two studies, with WHO data underestimating the BMI of Québec youth.

Table 4 The prevalence of overweight and obesity according to age and sexes among Québec youth

Age (yrs)	Total (N)	OW (N)	OB (N)	OW (%)	CI 95% (%)	OB (%)	CI 95% (%)	Total OW/OB (%)	CI 95% (%)
Males									
6	92	6	5	6.5	0.0 – 16.9	5.4	0.0 – 15.9	11.9	1.5 – 22.4
7	162	15	3	9.3	1.4 – 17.1	1.9	0.0 – 9.7	11.2	3.3 – 19.0
8	224	18	8	8.0	1.4 – 14.7	3.6	0.0 – 10.3	11.6	4.9 – 18.3
9	213	24	7	11.3	4.4 – 18.1	3.3	0.0 – 10.1	14.6	7.7 – 21.4
10	232	23	12	9.9	3.3 – 16.5	5.2	0.0 – 11.7	15.1	8.5 – 21.7
11	189	20	14	10.6	3.3 – 17.9	7.4	0.0 – 14.7	18.0	10.7 – 25.3
12	243	41	20	16.9	10.5 – 23.3	8.2	1.8 – 14.6	25.1	18.7 – 31.5
13	248	55	21	22.2	15.8 – 28.5	8.5	2.1 – 14.8	30.7	24.3 – 37.0
14	188	28	19	14.9	7.6 – 22.2	10.1	2.8 – 17.4	26.0	17.7 – 32.3
15	213	33	21	15.5	8.6 – 22.3	9.9	3.0 – 16.7	25.4	18.5 – 32.2
16	188	33	15	17.6	10.3 – 24.8	8.0	0.1 – 15.3	25.6	18.2 – 32.8
17	103	18	10	17.5	7.6 – 27.3	9.7	0.0 – 19.6	27.2	17.3 – 37.0
Total	2296	314	155	13.7		6.8		20.5	
Females									
6	109	10	3	9.2	0.0 – 18.8	2.8	0.0 – 12.3	12.0	2.3 – 21.5
7	182	21	8	11.5	4.1 – 19.0	4.4	0.0 – 11.8	15.9	8.5 – 23.3
8	214	25	14	11.7	4.8 – 18.5	6.5	0.0 – 13.4	18.2	11.4 – 25.1
9	229	28	8	12.2	5.6 – 18.8	3.5	0.0 – 10.1	15.7	9.1 – 22.3
10	223	30	13	13.5	6.8 – 20.1	5.8	0.0 – 12.5	19.3	12.6 – 26.0
11	233	31	13	13.3	6.8 – 19.9	5.6	0.0 – 12.1	18.9	12.3 – 25.4
12	275	56	20	20.4	14.3 – 26.4	7.3	1.2 – 13.3	27.7	21.6- 33.7
13	219	39	21	17.8	11.1 – 24.6	9.6	2.8 – 16.3	27.4	20.6 – 34.2
14	159	34	22	21.4	13.5 – 29.3	13.8	5.9 – 21.8	35.2	27.3 – 43.2
15	122	19	8	15.6	6.5 – 24.6	6.6	0.0 – 15.6	22.2	13.1 – 31.2
16	148	24	12	16.2	8.0 – 24.4	8.1	0.0 – 16.3	24.3	16.1 – 32.5
17	89	13	7	14.6	4.0 – 25.2	7.9	0.0 – 18.5	22.5	11.9 – 33.1
Total	2204	330	149	15.0		6.8		21.8	

Yrs Years, *N* Number of participants, % Percentage, *OW* Overweight, *OB* Obese

A detailed description of the impacts of SES and area of residence (large versus small urban areas) is presented in Table 3. The overall prevalence of overweight/obesity in high-income is 14.4%, compared to 26.0% for children who came from low-income environments (see Supplementary Materials Fig. 4). We also note that youth from large urban areas have a prevalence of 21.0% compared to 17.1% in the small urban cities (see Supplementary Materials Fig. 5). Finally, the odds ratio of being overweight/obese is 2.1 times higher in a low-income environment and 1.3 times higher in a large urban area.

Table 4 provides a clear picture of the distribution of obesity prevalence according to age and sex. The data presented show a progressive increase with age in the occurrence of overweight/obesity with a marked jump in adolescence. This trend is quite similar among males and females. Supplementary material Table 8 shows that for the entire age range (6 to 17 years), males in 2017 have a BM gain of 6.5 kg (13.7%) for a rise in BH of 1.7 cm (3.2%) and an increase in BMI of 1.4 kg/m^2 (19.4%) compared to 1982. There is a larger trend in females with an increase of 7.4 kg (19.0%) for BM, 2.0 cm (4.6%) for BH and 1.3 kg/m^2 (20.3%) for BMI. For both sexes, it seems clear that BM gain is significantly greater than BH gain, which explains the increase in BMI.

Discussion

This study provided a unique opportunity to update the BM, BH and BMI data of youth in the Québec population under the same conditions as those applied by Léger and Lambert in 1983 (i.e. same evaluation procedures, school boards, cities and age groups), which makes these two studies highly comparable. The implementation of body mass for body height corrections as suggested by the WHO (2006) has provided a more realistic picture of the current situation.

The secular trend of the last 50 years reflects many important anthropometric changes. Between 1972 and 2017, the

BM and BMI of Québec youth increased considerably. For comparison purposes, the Léger and Lambert study (1983) is of particular interest due to the many similarities with the present study. By comparing both studies, it becomes evident that the substantial surge in BM and BMI observed between 1982 and 2017 highlights the persistent prevalence of the secular trend with regard to these two variables. At the end of the growth period under consideration, the difference in body mass gain represents 6.5 kg in males and 7.4 kg in females since 1982. This difference is probably not attributable to methodological variations since the equipment used, the cities selected, the measurement protocols applied, the participating school boards, and the team of evaluators made up of physical educators were equivalent if not identical to those in 1982. Even the composition of the measured population remained relatively stable. Montreal and Laval were and are still highly multi-ethnic cities, while the other cities in the study are still composed of a much more homogeneous population. Poor lifestyle habits such as increased consumption of unhealthy food as well as increased time spent in passive activities are perhaps the best explanation for these changes (Gallant et al., 2020; Popkin & Ng, 2022; Public Health Agency of Canada, 2011; Shields, 2006).

The growth trend for BH exhibits a distinct pattern. The 2017 data highlight a higher BH in today's males for almost the entire growth period. However, the BH attained by age 17 has remained similar since 1972, indicating that males are likely maturing earlier in contemporary times. This difference in maturation can be partially explained by the increase in cases of obesity which is associated with early maturation in both sexes (O'Keeffe et al., 2020). The situation differs for females, as we observe a 2 cm increase in final height at age 17 among adolescent females in 2017, suggesting that the secular trend for BH continues.

As reported by Léger and Lambert in 1983, Canadian growth charts are not an appropriate surveillance tool for the Québec youth population. While in 1982, the Québec youth of both sexes were lighter and shorter than the other Canadians, particularly after the age of 10, this trend has drastically changed, especially for BMI. The difference can now represent nearly 1.5 kg/m^2 for the same chronological age for Québec youth. The Canadian growth curve charts presented by the WHO show that prior to puberty, Québec youth tend to be slightly taller than their Canadian peers, but by age 17, they are surpassed by 2 cm in males and 1 cm in females (Fig. 3). This trend seems to support the possibility of earlier maturation in 2017 youth as previously discussed.

Québec youth from low-income backgrounds are nearly twice as likely to be overweight or obese (26.0% versus 14.4% respectively). This is consistent with the odds ratio value (odds ratio: 2.1) which indicates that low-income youth are twice as likely to become overweight or obese. Young males (6–11 years old) seem more sensitive to the effect of income level (odds ratio: children 1.7 vs adolescents 1.3) whereas this situation is different for females (odds ratio: children 1.1 vs adolescents 1.7). As part of an intervention program, it is therefore important to consider age and sex in order to establish a strategy that maximizes the chances of reducing inequalities.

The proportions between low and high incomes observed are very similar to those reported by Rao and colleagues in 2016 for Canadian youth. However, we note that their percentages are considerably higher for overweight or obesity. This discrepancy is not very surprising since youth in Québec generally have overweight and obesity percentages below the Canadian average (Public Health Agency of Canada, 2011). This clearly illustrates the importance of taking regional specificities into account in order to better target the future actions.

Area of residence is another important factor to consider. In 2004, Mitura and Bollman reported higher rates of overweight and obesity among Canadian adolescents residing in small urban as compared with large urban cities (27% vs. 22% respectively). In this study, the opposite effect was found (23% small vs. 33% large urban cities). Since 2004, urban sprawl has grown considerably. In addition, the many advertising campaigns promoting active transportation are perhaps better received in small urban cities, especially since public transportation is often less accessible and less efficient. Specific studies on this issue are required. In addition, perhaps children and adolescents from large centres are less likely to play outdoors in unsupervised physical activities.

The prevalence of overweight and obesity in youth has become a major public health concern. Some Canadian studies suggest a kind of stabilization of the evolution of obesity over the past two decades (Rao et al., 2016). According to the National Institute of Public Health of Québec (Lamontagne and Hamel, 2009), about 7.1% of young people in Québec aged 6–17 suffered from obesity at that time. This percentage is now 6.8%, suggesting some form of stabilization. A similar trend is also present for overweight (15.5% in 2004 vs. 14.4% in 2017). It is therefore encouraging to note that cases of overweight and obesity have not increased between 2004 and 2017 in both sexes. It remains to be seen how the COVID-19 pandemic has impacted those rates.

Strengths and limitations

The large sample size ($n = 4500$) provides a valid representation of Québec youth. The reported values were measured rather than self-reported, resulting in reduced biases. The procedure used was repeated under the same conditions as the 1982 study by Léger and Lambert, which allows for the assessment of secular trends with a reduced number of biases. However, some limitations should also be noted. The cross-sectional nature of the data restricts inferences. Although some towns were in small urban areas, cities in rural zones were not represented.

Conclusion

Updating measured anthropometric values, as opposed to self-reported ones, is essential in a context of close population surveillance. These updated data will enable clinicians to more accurately track the physical development of their young patients. As well, some trends appear to be confirmed. Overweight and obesity rates seem to be stabilizing since 2004, which is good news in itself. In this regard, the deprivation index as proposed by the Québec Ministry of Education, although imperfect, remains associated with youth at risk of developing overweight or obesity. However, some factors such as the impact of urban sprawl need to be better documented.

Contributions to knowledge

What does this study add to existing knowledge?

- Since the last update essentially dates from nearly 40 years ago, the first contribution of this study is to provide clinicians an update of measured normative values for body mass, body height and body mass index (BMI) specific to Québec youth aged 6.0 to 17.9 years.
- This study draws a detailed picture of the secular trends of anthropometric parameters (body mass, body height and BMI) from 1972 to 2017.
- Current data on the evolution of overweight and obesity according to different socioeconomic factors such as low income level and place of residence in relation to age and sex are also analyzed.

What are the key implications for public health interventions, practice or policy?

- The results presented reduce the number of biases and therefore improve the clinical monitoring of youth by taking into account the specificities of the Québec population.
- Data clearly demonstrate the importance of ensuring socioeconomic surveillance in order to counter childhood overweight and obesity (there is no one-size-fits-all solution).
- The findings of this study reinforce the importance of developing a surveillance system based on data gathered over a shorter time interval in order to better target and modulate the type and nature of the most effective intervention strategies.

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Author contributions ML was involved in study conceptualization and design, data collection, data analysis and drafting of the initial and final manuscripts.

MA and EK coordinated and supervised data collection, contributed to the study design, drafted the initial manuscript, and reviewed and revised the final manuscript.

HTB and JL participated in the study design, initial analyses, and data collection, drafted the initial manuscript, and reviewed and revised the final manuscript.

LL, GL and DG were involved in study conceptualization, data analysis, and review and drafting of the final manuscript.

PL coordinated and supervised data collection, was involved in initial data analysis, drafted the initial manuscript, and reviewed and revised the final manuscript.

SBG was involved in the data collection, initial data analysis, drafting of the initial manuscript, and review and revision of the final manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Availability of data and materials All material and data used for this paper are available upon reasonable request to the corresponding author.

Code availability All figures were produced using IBM-SPSS version 24 software and retouched with Microsoft Paint software.

Declarations

Ethics approval The Institutional Ethical Committee Board of University of Québec in Chicoutimi approved the project (no: 602–225-01).

Consent to participate Parents and students were informed of the project and could indicate their willingness to participate or not (a consent form was signed by the school authorities). Participants could withdraw at any time, without prejudice.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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