Prevalence of cardiometabolic risk factors by weight status in a population-based sample of Quebec children and adolescents

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M Lambert, EE Delvin, E Levy, et al. Prevalence of cardiometabolic risk factors by weight status in a population-based sample of Quebec children and adolescents. Can J Cardiol 2008;24(7):575-583.

BACKGROUND: There are few data on the prevalence of cardiometabolic risk factors in population-based samples of overweight and obese youth.
OBJECTIVES: To compare the prevalence of individual and multiple cardiometabolic risk factors across body mass index (BMI) categories in a population-based sample of youth.
METHODS: In 1999, a school-based survey of a provincially representative sample of youth nine, 13 and 16 years of age was conducted in Quebec (1778 boys, 1835 girls). Overweight was defined as BMI in the 85th percentile or higher and lower than the 95th percentile of the Centers for Disease Control and Prevention 2000 growth charts, and obesity was defined as BMI in the 95th percentile or higher. Levels of total cholesterol, low-density lipoprotein cholesterol, apolipoprotein B, high-density lipoprotein cholesterol, triglycerides, insulin, glucose, C-reactive protein and systolic blood pressure were categorized as desirable, borderline or unfavourable.
RESULTS: The proportions of overweight and obese participants were 14% and 10% in boys, and 14% and 7% in girls, respectively. With the exception of total cholesterol and low-density lipoprotein cholesterol in girls, and glucose in both sexes, the prevalence of all investigated risk factors (borderline or unfavourable) was significantly higher among overweight and obese participants. Almost one-third of obese participants had unfavourable levels of at least two of seven risk factors (apolipoprotein B, high-density lipoprotein cholesterol, triglycerides, insulin, glucose, C-reactive protein and systolic blood pressure) compared with 3% of normal weight participants (adjusted OR 15 and 18 in boys and girls, respectively). Thirty-four per cent of obese youth did not have unfavourable levels of any risk factor.
CONCLUSION: There is marked heterogeneity in the association between excess weight and cardiometabolic risk factors. Nonetheless, the present study highlights a high prevalence of multiple risk factors in a population-based sample of overweight and obese youth.

Key Words: *Cardiovascular risk factors; Obesity; Pediatrics; Population health*

La prévalence des facteurs de risque cardiométaboliques selon le poids au sein d'un échantillon démographique d'enfants et d'adolescents du Québec

HISTORIQUE : On possède peu de données sur la prévalence des facteurs de risque cardiométaboliques dans des échantillons démographiques de jeunes qui sont obèses ou font de l'embonpoint.
OBJECTIFS : Comparer la prévalence des facteurs de risque cardiométaboliques individuels et multiples selon les catégories d'indice de masse corporelle (IMC) d'un échantillon démographique de jeunes.
MÉTHODOLOGIE : En 1999, une enquête en milieu scolaire auprès d'un échantillon de jeunes de neuf, 13 et 16 ans représentatifs de la province a été menée au Québec (1 778 garçons, 1 835 filles). L'embonpoint y était défini comme un IMC situé entre le 85e et le 95e percentile des courbes de croissance 2000 des *Centers for Disease Control and Prevention*, et l'obésité, comme un IMC situé au moins dans le 95e percentile. Les taux de cholestérol total, de cholestérol à lipoprotéines de basse densité, d'apolipoprotéines B, de cholestérol à lipoprotéines de haute densité, de triglycérides, d'insuline, de glucose, de protéine C-réactive et de tension artérielle systolique étaient classés comme désirables, limite ou défavorables.
RÉSULTATS : Les proportions de participants qui faisaient de l'embonpoint ou étaient obèses s'élevaient à 14 % et 10 % chez les garçons et à 14 % et 7 % chez les filles, respectivement. À l'exception du cholestérol total et du cholestérol à lipoprotéines de basse densité chez les filles et du glucose chez les deux sexes, la prévalence de tous les facteurs de risque explorés (limite ou défavorables) était considérablement plus élevée chez les participants qui faisaient de l'embonpoint ou étaient obèses. Près du tiers des participants obèses présentaient des taux défavorables d'au moins deux des sept facteurs de risque (apolipoprotéine B, cholestérol à lipoprotéine de haute densité, triglycérides, insuline, glucose, protéine C-réactive et tension artérielle systolique) par rapport à 3 % des participants de poids normal (RR rajusté de 15 et 18 chez les garçons et les filles, respectivement). Trente-quatre pour cent des jeunes obèses ne présentaient aucun taux de facteur de risque défavorable.
CONCLUSION : On constate une hétérogénéité marquée dans l'association entre l'excès de poids et les facteurs de risque cardiométaboliques. Néanmoins, la présente étude met en lumière la prévalence des facteurs de risque multiples dans un échantillon démographique qui fait de l'embonpoint ou est obèse.

Over the past two decades, the prevalence of overweight and obesity has almost tripled among youth in the United States and Canada (1,2). This increased prevalence is now viewed as an 'epidemic and public health crisis' (3-5). Severe obesity in children has been associated with carotid arterial wall stiffness and brachial artery endothelial dysfunction, which are established markers of atherosclerosis (6). Recently, the investigators of the Bogalusa Heart Study (7), the Cardiovascular Risk in Young Finns Study (8) and the Atherosclerosis Risk in Young Adults Study (9) reported that body mass index (BMI) measured in childhood or adolescence predicted carotid intima-media thickness in young adults. In a clinic-based sample of children and adolescents with severe obesity (10), impaired

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Received for publication August 25, 2007. Accepted November 18, 2007

TABLE 1
Thresholds used to define 'at risk' levels for selected metabolic characteristics

	Category		
Risk factor	**Desirable**	**Borderline**	**Unfavourable**
Total cholesterol (mmol/L)	<4.4	4.4 to <5.2	≥5.2
LDL cholesterol (mmol/L)	<2.6	2.6 to <3.4	≥3.4
Apolipoprotein B (g/L)	<0.75	0.75 to <1.0	≥1.0
HDL cholesterol* (mmol/L)	≥1.0	0.9 to <1.0	< 0.9
Triglycerides (mmol/L)	<1.7	1.7 to 2.3	≥2.3
Insulin (pmol/L)			
9-year-olds	<38	38 to <60	≥60
13- and 16-year-olds	<60	60 to <100	≥100
Glucose (mmol/L)	<5.6	5.6 to <6.1	≥6.1
C-reactive protein (mg/L)	<3.0	NA	≥3.0

**In contrast to the other factors, borderline low or low high-density lipoprotein (HDL) cholesterol values are associated with the risk of cardiovascular disease. LDL Low-density lipoprotein; NA Not applicable*

glucose tolerance was highly prevalent, irrespective of ethnic origin. Excess body weight in children and adolescents has important implications for their risk of disease, particularly cardiovascular disease and diabetes.

The American Academy of Pediatrics (AAP) (11) and the Canadian Pediatric Society (12) recommend the use of BMI-for-age to screen children from two years of age and onward to identify those who may be at risk for morbidity related to excess body fat. Although numerous studies document associations between excessive adiposity and dyslipidemia, hyperinsulinemia, elevated C-reactive protein (CRP), high blood pressure (BP) and risk factor clustering in youth (13-22), there are few data on the prevalence of these cardiometabolic risk factors in population-based samples of children and adolescents stratified by weight status (22-29). Moreover, the risk factors assessed and the cutpoints used to define higher risk differ substantially across studies. However, population-level information can serve as benchmarks for physicians who care for overweight and obese children and who need to evaluate the risk associated with excess body fat. This information is also very valuable for public health specialists and policy makers, who estimate the current and future burden of disease associated with childhood obesity and need baseline data to track population-wide changes resulting from new health policies and programs. The objectives of the present study were to determine the prevalence of adverse levels of lipids, insulin, glucose, CRP and systolic BP in a population-based sample of Quebec children and adolescents; to compare the prevalence of these risk factors across BMI categories; to describe the number of risk factors per individual across BMI category; and to compare the prevalence of multiple risk factors between youth who are overweight or obese with those who do not have excess weight.

METHODS

Study population

The study population included participants in the Quebec Child and Adolescent Health and Social Survey (QCAHS) (30), a school-based survey conducted between January and May 1999 in the province of Quebec. The survey design and methods have been reported previously (30) and are only summarized here. The QCAHS used a cluster sampling design to draw three independent, age-specific, provincially representative samples of youth nine, 13 and 16 years of age. The sampling frame represented 97% of all youth targeted. Response percentages for questionnaires and anthropometric measurements were 80% for both boys (1778 of 2221 eligible) and girls (1835 of 2292). Eighteen participants (11 boys and seven girls) were excluded because they self-reported having diabetes (any type). Among the remaining participants (1767 boys and 1828 girls), BP was recorded for 1736 boys and 1799 girls (both 98%), and fasting lipids and glucose were available for 1192 boys (67%) and 1254 girls (69%). Insulin and CRP were measured in only 1076 boys and 1146 girls because 107 parents refused consent for blood analyses other than glucose and lipids, and 117 samples were thawed on arrival at the laboratory or were of an insufficient amount. Age-specific comparisons of youth who provided blood samples (n=2446) with those who did not (n=1149) revealed no statistically significant differences in sex, cigarette smoking, mean BMI, parental income or parental education. The Ethics Review Board of the CHU Sainte-Justine (Montreal, Quebec) approved the study. Informed written assent and consent were obtained from participants and their legal guardians, respectively.

Clinical variables

Height and weight were measured according to standardized protocols (30). BMI was computed as weight in kg divided by height in m^2. BP was measured on the right arm, with the child in a sitting position and at rest for at least 5 min, using an oscillometric instrument (model CR9340; Dinamap XL, USA). Three consecutive measures were obtained at 1 min intervals, and the average of the last two measures was used in the analyses. The physical activity score was based on a one-week recall modified from Sallis et al (31). Boys and girls were asked to indicate which of 21 activities they had participated in for at least 15 min on each of the previous seven days. Their responses were summed to create a physical activity score (maximum possible score = 147); higher physical activity scores represented greater participation. Current smokers were defined as those who answered 'yes' to the following question: "During the past 30 days, did you smoke cigarettes, even just a few puffs?" This question was not asked of nine-year-olds because only 2.1% of subjects that age answered 'yes' to the following question: "Have you ever smoked a whole cigarette?". All nine-year-olds were therefore classified as nonsmokers. Household income category was based on total household income and size of household. Ethnic origin (French-Canadian and other) was self-reported.

Biochemical analysis

Blood was obtained by venipuncture between 08:00 and 10:00 after an overnight fast in a 1 g/L EDTA collection tube that was kept on ice until centrifugation. Plasma was separated on-site within 45 min of collection, frozen on dry ice and sent within 24 h to the laboratory, where specimens were stored at –80°C until analysis. Nurses checked the adequacy of the fasting period before drawing blood. The median duration of the fasting period was 13 h (range 9 h to 17 h). Fasting plasma insulin, glucose, total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C) and CRP concentrations were measured as previously described (20,30,32). Low-density lipoprotein cholesterol (LDL-C) was calculated according to the Friedewald formula (33). Apolipoprotein B (apoB) concentrations were determined by nephelometry (Beckman Array Protein System; Beckman Coulter Inc, USA).

Definition of risk

Overweight was defined as BMI in the 85th percentile or higher and lower than the 95th age- and sex-specific percentile of the Centers for Disease Control and Prevention 2000 growth charts, and obesity was defined as BMI in the 95th percentile or higher (11,12,34). Each participant was classified as having a desirable, borderline or unfavourable level for each of nine metabolic and vascular characteristics. Table 1 shows the threshold values. Systolic BP was categorized according to the recommendations of the National High Blood Pressure Education Program (NHBPEP) (35) such that BP higher than in the 90th age-, sex- and height-specific percentile but lower than the 95th, and BP higher than the 95th percentile values were defined as borderline and unfavourable, respectively. Categorization

TABLE 2
Participant characteristics

Characteristic	Boys	Girls	P*
Age, % (95% CI) (1736 boys, 1799 girls)†			
9 years	34.1 (31.6–36.8)	33.9 (31.3–36.6)	0.913
13 years	32.4 (29.9–35.0)	31.9 (29.3–34.5)	
16 years	33.5 (30.9–36.1)	34.2 (31.6–36.9)	
French Canadian, % (95% CI) (1736 boys, 1799 girls)	80.5 (78.3–82.6)	77.1 (74.7–79.4)	0.034
Household income category, % (95% CI) (1371 boys, 1447 girls)			
Very poor/poor	16.5 (14.3–18.9)	16.7 (14.5–19.2)	0.712
Middle class inferior	30.8 (28.0–33.7)	28.8 (26.0–31.7)	
Middle class superior	35.0 (32.1–38.1)	37.2 (34.2–40.2)	
Superior	17.7 (15.4–20.2)	17.3 (15.0–19.8)	
Smoker, % (95% CI) (1736 boys, 1799 girls)	15.4 (13.5–17.5)	20.4 (18.3–22.7)	0.0008
BMI category‡, % (95% CI) (1736 boys, 1799 girls)			
9-year-olds			
Overweight	14.5 (11.4–18.1)	13.5 (10.4–17.0)	0.829
Obese	9.3 (6.8–12.4)	8.6 (6.1–11.6)	
13-year-olds			
Overweight	14.0 (10.8–17.6)	12.3 (9.3–15.9)	0.338
Obese	10.1 (7.4–13.4)	7.8 (5.4–10.8)	
16-year-olds			
Overweight	12.7 (9.7–16.2)	14.8 (11.6–18.4)	0.060
Obese	9.5 (6.9–12.6)	5.4 (3.5–8.0)	
BMI, kg/m^2 (mean ± SD) (1736 boys, 1799 girls)	20.3±4.1	20.2±4.3	0.701
Blood pressure, mmHg (mean ± SD) (1736 boys, 1799 girls)			
9-year-olds			
Systolic	103.3±9.5	102.7±9.7	0.189
Diastolic	57.0±6.3	56.8±6.1	0.613
13-year-olds			
Systolic	113.1±12.0	111.1±11.0	0.0036
Diastolic	58.4±6.8	59.6±6.8	0.015
16-year-olds			
Systolic	124.3±13.6	114.2±11.2	<0.0001
Diastolic	61.2±7.1	62.3±7.5	0.012
Physical activity score, mean ± SD (1720 boys, 1793 girls)	10.1±8.6	7.6±6.5	<0.0001
Lipids, mmol/L (mean ± SD) (1192 boys, 1254 girls)			
Total cholesterol	3.83±0.70	4.13±0.77	<0.0001
Low-density lipoprotein cholesterol	2.20±0.58	2.40±0.66	<0.0001
High-density lipoprotein cholesterol	1.25±0.25	1.32±0.24	<0.0001
Triglycerides	0.84±0.45	0.91±0.41	<0.0001
Apolipoprotein B, g/L (mean ± SD) (1138 boys, 1202 girls)	0.63±0.16	0.69±0.19	<0.0001
Glucose, mmol/L (mean ± SD) (1192 boys, 1254 girls)	5.3±0.4	5.1±0.4	<0.0001
Insulin, pmol/L (mean ± SD) (1076 boys, 1147 girls)			
9-year-olds	29.4±21.2	35.5±46.2	0.026
13- to 16-year-olds	47.6±36.1	53.4±29.6	<0.0001
C-reactive protein, mg/L (median, range§) (1076 boys, 1146 girls)	0.2, ND – 55.3	0.3, ND – 65.6	<0.0001

**P for differences between sexes; †Number of participants for whom data were available; ‡No excess weight – body mass index (BMI) <85th age- and sex-specific percentile values according to the Centers for Disease Control and Prevention 2000 growth charts, overweight – BMI ≥85th and <95th age- and sex-specific percentile values, obese – BMI ≥95th age- and sex-specific percentile values; §Median and range were used instead of mean ± SD because a large proportion of participants had nondetectable (ND) concentrations*

of TC, LDL-C, HDL-C and TG was based on recommendations from the American Heart Association (AHA) and the AAP (36), with some modifications, because there is no borderline category for HDL-C and TG in either the AHA or the AAP recommendations. The threshold of 0.9 mmol/L to define unfavourable HDL-C has been used in other pediatric studies (24). The threshold of 1.7 mmol/L to define the lower boundary of the borderline category for TG has been used by many investigators (26,28) and corresponds to the threshold used to define elevated TG as a criterion of the metabolic syndrome according to the definition of the National Cholesterol Education Program's Adult Treatment Panel III (37). No widely accepted guidelines are available for the categorization of insulin and apoB; the lower limits for the borderline and unfavourable categories correspond approximately to the 75th and 95th percentile values of the QCAHS distributions, respectively. Fasting blood glucose of 5.6 mmol/L or higher and lower than 6.1 mmol/L was classified as borderline, and values 6.1 mmol/L or higher were classified as unfavourable (38). CRP concentrations of 3.0 mg/L or higher were classified as unfavourable based on the AHA recommendations (39).

TABLE 3
Proportion of boys with borderline or unfavourable levels of selected risk factors by body mass index (BMI) category

	BMI category*			
Risk factor, % (95% CI)	No excess weight	Overweight	Obese	P†
Systolic blood pressure	(n=1325)	(n=238)	(n=173)	
Borderline	5.3 (4.1–6.9)	7.9 (4.5–12.6)	8.5 (4.4–14.5)	
Unfavourable	11.2 (9.4–13.2)	20.9 (15.4–27.3	31.1 (23.5–39.6)	
Borderline + unfavourable	16.5 (14.4–18.9)	28.8 (22.5–35.7)	39.6 (31.4–48.4)	<0.0001
Total cholesterol	(n=916)	(n=155)	(n=121)	
Borderline	14.2 (11.8–16.9)	21.5 (14.7–29.7)	26.0 (17.7–35.7)	
Unfavourable	2.7 (1.6–4.1)	7.9 (3.8–14.0)	5.8 (2.1–12.3)	
Borderline + unfavourable	16.9 (14.2–19.7)	29.4 (21.7–38.1)	31.8 (22.7–41.9)	<0.0001
Low-density lipoprotein cholesterol	(n=916)	(n=155)	(n=121)	
Borderline	15.5 (13.0–18.3)	21.6 (14.8–29.8)	33.3 (24.1–43.5)	
Unfavourable	2.5 (1.5–3.9)	6.7 (3.0–12.5)	4.5 (1.4–10.7)	
Borderline + unfavourable	18.0 (15.3–20.9)	28.3 (20.7–36.9)	37.8 (28.3–48.1)	<0.0001
Apolipoprotein B	(n=880)	(n=148)	(n=110)	
Borderline	14.4 (11.9–17.2)	26.7 (19.1–35.5)	32.1 (22.6–42.8)	
Unfavourable	1.1 (0.5–2.1)	6.1 (2.5–11.9)	10.1 (4.7–18.3)	
Borderline + unfavourable	15.5 (12.9–18.3)	32.8 (24.5–41.9)	42.2 (31.8–53.1)	<0.0001
High-density lipoprotein cholesterol	(n=916)	(n=155)	(n=121)	
Borderline	7.0 (5.2–9.0)	10.8 (6.0–17.5)	17.1 (10.3–26.0)	
Unfavourable	4.4 (3.0–6.1)	3.3 (1.0–8.1)	8.6 (3.9–16.0)	
Borderline + unfavourable	11.4 (9.2–13.8)	14.1 (8.6–21.4)	25.7 (17.5–35.5)	0.0003
Triglycerides	(n=916)	(n=155)	(n=121)	
Borderline	0.8 (0.3–1.7)	7.3 (3.5–13.3)	12.7 (6.9–20.9)	
Unfavourable	0.2 (0.02–0.9)	4.4 (1.6–9.6)	4.8 (1.5–11.0)	
Borderline + unfavourable	1.0 (0.4–2.0)	11.7 (6.7–18.6)	17.5 (10.6–26.4)	<0.0001
Glucose	(n=916)	(n=155)	(n=121)	
Borderline	14.3 (11.9–17.0)	19.4 (12.9–27.3)	22.7 (14.9–32.2)	
Unfavourable	2.1 (1.2–3.4)	5.0 (1.9–10.4)	2.0 (0.2–7.1)	
Borderline + unfavourable	16.4 (13.8–19.2)	24.4 (17.2–32.8)	24.7 (16.6–34.4)	0.02
Insulin	(n=830)	(n=141)	(n=105)	
Borderline	10.4 (8.2–12.9)	26.8 (19.0–35.8)	45.1 (34.3–56.2)	
Unfavourable	0.9 (0.3–1.9)	10.4 (5.5–17.4)	27.0 (18.0–37.6)	
Borderline + unfavourable	11.3 (9.0–13.9)	37.2 (28.4–46.6)	72.1 (61.3–81.2)	<0.0001
C-reactive protein	(n=830)	(n=141)	(n=105)	
Unfavourable	6.3 (4.6–8.3)	5.9 (2.4–11.9)	17.7 (10.3–27.5)	0.0005

**No excess weight – BMI <85th age- and sex-specific percentile values according to the Centers for Disease Control and Prevention 2000 growth charts, overweight – BMI ≥85th and <95th age- and sex-specific percentile values, obese – BMI ≥95th age- and sex-specific percentile values; †P for differences across BMI categories using χ^2 statistics. n Number of participants for whom data were available*

Statistical analyses

To take the complex study design into account, sampling weights and design effects were estimated and incorporated into computations of prevalence. The associations between sex and continuous variables (BMI, BP, physical activity score, lipids, apoB, glucose and insulin) were tested in univariate regression analysis. Sex-specific OR for the presence of risk factors in overweight and obese participants compared with participants with no excess weight, and in 13- and 16-year-olds compared with nine-year-olds were modelled in multivariable logistic regression that adjusted for covariates, including household income, smoking status and physical activity score. Models were fitted based on the generalized estimating equations approach to take clustering within schools into account, using the exchangeable correlation structure. A conservative level of significance ($P \leq 0.01$) was used to account for multiple statistical testing, and findings with lower levels of significance were interpreted with caution. Because the analyses showed clinically meaningful and statistically significant differences by sex on many variables of interest, all analyses were conducted separately for boys and girls. Statistical analyses were performed with SAS statistical software (version 9.1; SAS Institute, Inc, USA) and SUDAAN (Research Triangle Institute, USA).

RESULTS

There were no significant differences in the profile of sociodemographic characteristics or in the prevalence of overweight and obesity according to sex (Table 2). Proportionately, more girls than boys were smokers. Physical activity scores were higher in boys than girls. Mean levels of BP and fasting plasma concentrations of lipids, apoB, glucose and insulin differed significantly by sex. Specifically, mean systolic BP in 13- and 16-year-olds, and glucose in all age groups were higher in boys than girls. In contrast, mean concentrations of TC, LDL-C, apoB, HDL-C, TG and insulin, and median concentrations of CRP were higher in girls than boys.

With the exception of TC and LDL-C in girls, and glucose in both sexes, the prevalence of all cardiometabolic risk factors was significantly higher among overweight and obese participants than among those with no excess weight (Tables 3 and 4). The risk factor that was most prevalent in obese youth was borderline or unfavourable insulin

TABLE 4
Proportion of girls with borderline or unfavourable levels of selected risk factors by body mass index (BMI) category

	BMI category*			
Risk factor, % (95% CI)	No excess weight	Overweight	Obese	P†
Systolic blood pressure	(n=1414)	(n=250)	(n=135)	
Borderline	4.5 (3.4–6.0)	12.3 (7.9–17.8)	8.0 (3.5–15.2)	
Unfavourable	7.3 (5.9–9.0)	15.1 (10.3–21.0)	32.5 (23.5–42.7)	
Borderline + unfavourable	11.8 (10.0–13.9)	27.4 (21.1–34.3)	40.6 (30.9–50.9)	<0.0001
Total cholesterol	(n=985)	(n=171)	(n=98)	
Borderline	24.5 (21.5–27.7)	20.7 (14.2–28.7)	27.5 (17.7–39.2)	
Unfavourable	6.5 (4.9–8.5)	13.8 (8.4–20.9)	3.3 (0.5–10.4)	
Borderline + unfavourable	31.0 (27.7–34.4)	34.5 (26.5–43.3)	30.8 (20.5–42.7)	0.715
Low-density lipoprotein cholesterol	(n=985)	(n=171)	(n=98)	
Borderline	25.8 (22.7–29.1)	30.3 (22.6–38.9)	38.0 (26.9–50.1)	
Unfavourable	5.4 (3.9–7.2)	12.6 (7.4–19.5)	2.5 (0.3–9.2)	
Borderline + unfavourable	31.2 (27.9–34.7)	42.9 (34.3–51.8)	40.5 (29.1–52.6)	0.014
Apolipoprotein B	(n=946)	(n=163)	(n=93)	
Borderline	23.2 (20.2–26.5)	29.2 (21.5–38.0)	39.0 (27.5–51.4)	
Unfavourable	4.0 (2.7–5.7)	13.0 (7.7–20.2)	5.8 (1.6–14.1)	
Borderline + unfavourable	27.2 (24.0–30.7)	42.2 (33.5–51.3)	44.8 (32.8–57.1)	0.0001
High-density lipoprotein cholesterol	(n=985)	(n=171)	(n=98)	
Borderline	3.1 (2.0–4.6)	10.7 (6.0–17.3)	10.7 (4.7–20.1)	
Unfavourable	2.4 (1.4–3.7)	1.4 (0.2–5.2)	7.6 (2.7–16.2)	
Borderline + unfavourable	5.5 (4.0–7.3)	12.1 (7.1–18.9)	18.3 (10.2–29.0)	<0.0001
Triglycerides	(n=985)	(n=171)	(n=98)	
Borderline	3.5 (2.3–5.0)	8.1 (4.1–14.1)	7.1 (2.4–15.6)	
Unfavourable	0.2 (0.02–0.9)	2.3 (0.5–6.6)	4.7 (1.1–12.4)	
Borderline + unfavourable	3.7 (2.5–5.3)	10.4 (5.8–16.9)	11.8 (5.4–21.5)	0.0002
Glucose	(n=985)	(n=171)	(n=98)	
Borderline	8.0 (6.2–10.2)	8.0 (4.0–14.0)	16.2 (8.6–26.6)	
Unfavourable	1.1 (0.5–2.1)	1.1 (0.07–4.7)	1.1 (0.01–7.0)	
Borderline + unfavourable	9.1 (7.1–11.4)	9.1 (4.8–15.4)	17.3 (9.4–27.9)	0.075
Insulin	(n=900)	(n=156)	(n=90)	
Borderline	21.2 (18.2–24.4)	34.1 (25.8–43.3)	48.1 (35.8–60.7)	
Unfavourable	2.0 (1.1–3.3)	12.2 (7.0–19.4)	31.9 (21.1–44.4)	
Borderline + unfavourable	23.2 (20.1–26.5)	46.3 (37.2–55.6)	80.1 (68.6–88.8)	<0.0001
C-reactive protein	(n=900)	(n=156)	(n=90)	
Unfavourable	8.4 (6.5–10.8)	14.1 (8.5–21.6)	29.1 (18.7–41.4)	<0.0001

**No excess weight – BMI <85th age- and sex-specific percentile values according to the Centers for Disease Control and Prevention 2000 growth charts, overweight – BMI ≥85th and <95th age- and sex-specific percentile values, obese – BMI ≥95th age- and sex-specific percentile values; †P for differences across BMI categories using χ^2 statistics. n Number of participants for whom data were available*

(72% and 80% in obese boys and girls, respectively). After exclusion of those who reported a previous diagnosis of diabetes (any type), no participant had a fasting glucose of 7.0 mmol/L or higher, which is the threshold used to define diabetes (38). The estimated prevalence of self-reported diabetes mellitus was 0.5% (95% CI 0.3% to 0.8%; 18 cases among 3613 participants).

After adjustment for covariates (age, smoking status, physical activity score and household income), obese boys and girls were at least three times more likely to have borderline or unfavourable levels of systolic BP, HDL-C, TG and insulin than same-sex participants with no excess weight (Table 5). Obese girls were 1.9 times more likely to have borderline or unfavourable concentrations of apoB relative to normal weight girls; the OR was 3.4 in obese boys. The OR was 5.2 among obese girls for borderline or unfavourable CRP compared with normal weight girls; the OR was 2.8 in obese boys.

Both overweight boys and girls were at least three times more likely to have borderline or unfavourable concentrations of TG and insulin relative to same-sex participants with no excess weight after adjustment for covariates (Table 5). Overweight boys were 1.9 times more likely to have borderline or unfavourable levels of systolic BP than normal weight boys; the OR was 3.5 in overweight girls. Relative to same-sex participants with no excess weight, overweight boys were two to three times more likely to have borderline or unfavourable TC and apoB, and overweight girls were two to three times more likely to have borderline or unfavourable HDL-C and CRP.

The prevalence of cardiometabolic risk factors differed with age. After adjustment for weight status and other covariates, 13- and 16-year-old boys and girls were two to five times more likely to have borderline or unfavourable systolic BP than same-sex nine-year-olds (Table 5). The risk of borderline or unfavourable TC was lower in 13- and 16-year old boys than in nine-year old boys, while the risk of borderline or unfavourable TC, LDL-C and apoB was lower in 13-year-old girls compared with nine-year-old girls. Sixteen-year-old boys were three to four times more likely to have borderline or unfavourable HDL-C, TG and glucose than nine-year-old boys.

The distribution of the number of risk factors per participant according to BMI category and sex is presented in Table 6. Because of the high correlations among TC, LDL-C and apoB concentrations (all Pearson's r>0.8) and because they are biologically related risk factors, only borderline or unfavourable apoB were included in

TABLE 5
OR for borderline or unfavourable levels of selected risk factors based on body mass index (BMI) category and age

	Boys		Girls	
Variable	**OR (95% CI)***	**P**	**OR (95% CI)***	**P**
A) Systolic blood pressure (1360 boys, 1444 girls)†				
BMI category‡				
No excess weight	1.0	–	1.0	–
Overweight	1.9 (1.3–2.8)	0.0024	3.5 (2.4–5.0)	<0.0001
Obese	3.3 (2.1–5.2)	<0.0001	4.7 (2.9–7.7)	<0.0001
Age				
9 years	1.0	–	1.0	–
13 years	2.4 (1.6–3.6)	<0.0001	1.8 (1.2–2.6)	0.0021
16 years	4.7 (3.2–6.9)	<0.0001	2.0 (1.3–3.0)	0.0011
B) Total cholesterol (1007 boys, 1071 girls)				
BMI category				
No excess weight	1.0	–	1.0	–
Overweight	2.1 (1.4–3.3)	0.0011	1.1 (0.7–1.6)	0.617
Obese	2.3 (1.5–3.7)	0.0002	0.9 (0.6–1.5)	0.763
Age				
9 years	1.0	–	1.0	–
13 years	0.6 (0.4–0.8)	0.011	0.5 (0.4–0.7)	0.0001
16 years	0.6 (0.4–0.9)	0.0016	0.8 (0.6–1.1)	0.182
C) Low-density lipoprotein cholesterol (1007 boys, 1071 girls)				
BMI category				
No excess weight	1.0	–	1.0	–
Overweight	1.6 (1.0–2.5)	0.031	1.6 (1.1–2.2)	0.0084
Obese	2.5 (1.6–3.9)	<0.0001	1.5 (1.0–2.4)	0.0614
Age				
9 years	1.0	–	1.0	–
13 years	0.8 (0.5–1.1)	0.134	0.6 (0.4–0.9)	0.010
16 years	0.7 (0.5–1.1)	0.161	0.8 (0.5–1.1)	0.128
D) Apolipoprotein B (966 boys, 1026 girls)				
BMI category				
No excess weight	1.0	–	1.0	–
Overweight	2.8 (1.8–4.4)	<0.0001	1.7 (1.2–2.4)	0.0013
Obese	3.4 (2.2–5.4)	<0.0001	1.9 (1.1–3.1)	0.014
Age				
9 years	1.0	–	1.0	–
13 years	0.8 (0.5–1.2)	0.320	0.6 (0.4–0.8)	0.0042
16 years	1.4 (0.9–2.2)	0.182	1.1 (0.8–1.7)	0.563
E) High-density lipoprotein cholesterol (1007 boys, 1071 girls)				
BMI category				
No excess weight	1.0	–	1.0	–
Overweight	1.2 (0.6–2.2)	0.645	2.4 (1.4–4.1)	0.0021
Obese	3.0 (1.8–5.1)	<0.0001	3.6 (1.9–6.9)	0.0001
Age				
9 years	1.0	–	1.0	–
13 years	1.7 (0.9–3.1)	0.097	2.0 (1.1–3.8)	0.024
16 years	4.2 (2.4–7.5)	<0.0001	2.0 (0.9–4.0)	0.068
F) Triglycerides (1007 boys, 1071 girls)				
BMI category				
No excess weight	1.0	–	1.0	–
Overweight	12.2 (5.0–29.4)	<0.0001	3.2 (1.7–6.2)	0.0005
Obese	16.1 (6.5–40.0)	<0.0001	3.9 (1.5–10.2)	0.0047
Age				
9 years	1.0	–	1.0	–
13 years	1.8 (0.7–4.3)	0.199	0.8 (0.3–2.1)	0.672
16 years	3.4 (1.5–7.9)	0.0035	1.3 (0.6–2.9)	0.445
G) Glucose (1007 boys, 1071 girls)				
BMI category				
No excess weight	1.0	–	1.0	–
Overweight	1.7 (1.0–2.8)	0.036	1.3 (0.7–2.4)	0.409
Obese	1.5 (0.9–2.6)	0.132	1.9 (1.0–3.7)	0.049
Age				
9 years	1.0	–	1.0	–
13 years	2.6 (1.6–4.2)	<0.0001	2.7 (1.5–4.7)	0.0009
16 years	2.6 (1.6–4.5)	0.0003	1.4 (0.7–2.6)	0.382
H) Insulin (907 boys, 975 girls)				
BMI category				
No excess weight	1.0	–	1.0	–
Overweight	4.9 (3.0–7.8)	<0.0001	3.2 (2.2–4.7)	<0.0001
Obese	18.2 (11.3–29.5)	<0.0001	15.7 (8.2–30.0)	<0.0001
Age				
9 years	1.0	–	1.0	–
13 years	1.1 (0.7–1.7)	0.805	1.5 (0.9–2.3)	0.109
16 years	0.7 (0.4–1.1)	0.156	1.2 (0.8–1.9)	0.434
I) C-reactive protein§ (907 boys, 975 girls)				
BMI category				
No excess weight	1.0	–	1.0	–
Overweight	0.9 (0.4–2.1)	0.900	2.0 (1.2–3.6)	0.013
Obese	2.8 (1.5–5.3)	0.0013	5.2 (2.7–9.7)	<0.0001
Age				
9 years	1.0	–	1.0	–
13 years	0.9 (0.5–1.9)	0.832	0.4 (0.2–0.7)	0.0050
16 years	1.8 (0.9–3.5)	0.092	2.0 (1.2–3.3)	0.0083

**Models are adjusted for household income, smoking status and physical activity score; †Number of participants for whom data were available. The 'n' differs from the 'n' reported in Tables 3 and 4 because of missing data on household income, smoking status and physical activity score; ‡No excess weight – BMI <85th age- and sex-specific percentile values according to the Centers for Disease Control and Prevention 2000 growth charts, overweight – BMI ≥85th and <95th age- and sex-specific percentile values, obese – BMI ≥95th age- and sex-specific percentile values; §In contrast to the other risk factors, the OR for unfavourable concentration of C-reactive protein by BMI category*

computation of the number of risk factors per individual. Increased concentrations of apoB are more closely associated with the metabolic syndrome than increased concentrations of TC and LDL-C (40). Forty-six per cent of obese boys had three or more of seven cardiometabolic risk factors (borderline or unfavourable apoB, TG, HDL-C, insulin, glucose and systolic BP, and high CRP) compared with 21% of overweight boys and 4% of boys with no excess weight. Forty-four per cent of obese girls had three or more of the seven risk factors compared with 24% of overweight girls and 7% of those with no excess weight. Compared with same-sex participants with no excess weight, obese boys and girls were 10 times more likely to have two or more borderline or unfavourable risk factors, while the OR was 4 in overweight boys and girls after adjustment for covariates (Table 7, part A).

TABLE 6
Distribution of the number of risk factors per participant by body mass (BMI) category

	Boys: BMI category*			Girls: BMI category*		
Number of risk factors†	No excess weight (n=830)	Overweight (n=141)	Obese (n=105)	No excess weight (n=900)	Overweight (n=156)	Obese (n=90)
A) Borderline or unfavourable, % (95% CI)						
0	46.4 (42.7–50.3)	22.8 (15.5–31.5)	7.1 (2.7–14.8)	42.3 (38.6–46.1)	24.0 (16.6–32.8)	5.4 (1.4–13.7)
1	34.9 (31.3–38.6)	31.0 (22.8–40.3)	19.7 (11.8–29.7)	34.6 (31.1–38.3)	27.2 (19.4–36.2)	22.0 (12.9–33.8)
2	14.4 (11.9–17.2)	24.8 (17.2–33.6)	27.4 (18.3–38.1)	16.6 (13.9–19.6)	24.4 (16.9–33.2)	28.4 (18.1–40.7)
≥3	4.3 (2.9–6.1)	21.4 (14.3–30.0)	45.8 (35.0–57.0)	6.5 (4.8–8.6)	24.4 (16.9–33.2)	44.2 (32.1–58.8)
P‡		<0.0001			<0.0001	
B) Unfavourable, % (95% CI)						
0	79.2 (74.9–81.2)	58.6 (49.1–67.7)	33.1 (23.3–44.2)	77.8 (74.6–80.9)	56.7 (47.3–65.9)	34.2 (23.1–46.7)
1	18.4 (15.5–21.5)	34.3 (25.7–43.7)	38.4 (28.0–49.6)	19.4 (16.5–22.5)	28.3 (21.4–37.4)	34.1 (23.0–46.7)
≥2	3.4 (2.2–5.1)	7.1 (3.1–13.4)	28.5 (19.2–39.3)	2.8 (1.7–4.3)	15.0 (9.0–22.7)	31.7 (20.9–44.1)
P‡		<0.0001			<0.0001	

**No excess weight – BMI <85th age- and sex-specific percentile values according to the Centers for Disease Control and Prevention 2000 growth charts, overweight – BMI ≥85th and <95th age- and sex-specific percentile values, obese – BMI ≥95th age- and sex-specific percentile values; †In A, the 7 risk factors included borderline or unfavourable levels of apolipoprotein B, triglycerides, high-density lipoprotein cholesterol, insulin, glucose and systolic blood pressure, and unfavourable C-reactive protein, as defined in Table 1 and the 'Methods' section. In B, the 7 risk factors included unfavourable levels of apolipoprotein B, triglycerides, high-density lipoprotein cholesterol, insulin, glucose, systolic blood pressure and C-reactive protein; ‡P for differences across BMI categories using χ^2 statistics. n Number of participants for whom data were available*

With a definition of risk factors limited to unfavourable levels of apoB, TG, HDL-C, insulin, glucose, systolic BP and CRP, 29% of obese boys and 32% of obese girls had two or more of these adverse cardiometabolic characteristics, compared with 3% of boys and girls with no excess weight (Table 6, part B). Obese boys were 15 times more likely and obese girls were 18 times more likely to have two or more risk factors than their counterparts with no excess weight (Table 7, part B). Sixteen-year-old boys were 10 times more likely to have two or more unfavourable risk factors than nine-year old boys, while 16-year-old girls were only two times more likely to have two or more of the same risk factors than nine-year-old girls.

DISCUSSION

Our study, the first to examine the prevalence of dyslipidemia and elevated insulin, glucose, CRP and systolic BP in a representative population-based sample of youth in Canada, supports the use of BMI-for-age as an effective screening tool for identifying children and adolescents at risk for adverse levels of lipids, insulin, CRP and systolic BP. The prevalence of borderline or unfavourable levels of all these metabolic and vascular characteristics was significantly higher in obese children and adolescents than in those with no excess weight. Moreover, 29% to 32% of obese participants had unfavourable levels of at least two of seven risk factors (apoB, HDL-C, TG, insulin, glucose, CRP and systolic BP), while only 3% of those with no excess weight had unfavourable levels of at least two of the same risk factors. It is notable that 34% of obese youth did not have unfavourable levels of any of the risk factors investigated, demonstrating heterogeneity in the association between excess body weight and cardiometabolic risk factors. Hence, the identification of youth with excess weight should be viewed as an indication for further assessment of associated cardiometabolic risk factors rather than a final diagnosis.

The presence of one or more cardiometabolic risk factors was common even in youth with no excess weight: 21% to 22% of normal weight boys and girls had at least one unfavourable risk factor. Determinants other than weight status are important in the pathophysiology of these risk factors. As expected, the prevalence of cardiometabolic risk factors differed across age groups. It is notable that 13-year-old boys were four times more likely and 16-year-old boys were 10 times more likely to have two or more unfavourable cardiometabolic characteristics than their nine-year-old counterparts.

In the QCAHS, 28% to 29% of overweight youth and 40% to 41% of obese youth had systolic BP in the 90th percentile or higher according to the NHBPEP charts (35). This is notably higher than the 9% for overweight adolescents and 11% for obese adolescents reported by Cook et al (25) in the US Third National Health and Nutrition Survey (NHANES III). Conversely, Sorof et al (41) reported that 38% of obese 10- to 19-year-olds had BP in the 95th percentile or higher according to the NHBPEP charts at first screening in the Houston Public School Study, percentages that are much closer to the prevalence of 30% to 33% observed among obese boys and girls in the QCAHS. Methodological issues may have contributed to the higher prevalence of high BP in the Houston Public School Study and the QCAHS. Automated oscillometric devices were used to measure BP in both studies, in contrast to auscultatory mercury manometers used in the NHANES III. In the QCAHS, all oscillometric devices were calibrated against a mercury manometer before beginning the survey, and in an independent validation study (19), we found no systematic differences between systolic BP measurements taken with a mercury manometer and an oscillometric device. However, other studies have found systematic differences in systolic BP measurements between oscillometric instruments and mercury manometers (42). Because hospitals and many clinics have mandated the removal of all mercury-containing equipment from patient care areas, oscillometric devices are now used almost exclusively for BP measurement in children. Development of oscillometric normative data is therefore needed.

Low HDL-C is a characteristic finding of the dyslipidemia associated with excess weight in adults. We found that 8% of obese boys and girls nine to 16 years of age had low values of HDL-C (lower than 0.9 mmol/L). In the Bogalusa Heart Study, Freedman et al (24) found that 7% of five- to 10-year-old children with a BMI between the 95th and 97th percentile values, and 16% of 11- to 17-year-old adolescents with a BMI between the 95th and 97th percentile values had low HDL-C (lower than 0.9 mmol/L). In the QCAHS, 26% and 18% of obese boys and girls, respectively, had HDL-C of 1.0 mmol/L or lower compared with 50% of obese youths in the NHANES III (25) and 19% in the Chicago Public Elementary Schools Study (27). Despite differences in the ethnic composition of the samples, the years in which data were collected and laboratory procedures, all four studies clearly support a higher prevalence of low HDL-C in obese children and adolescents. Another hallmark of the dyslipidemia associated with excessive adiposity is elevated TG. We found that

TABLE 7
OR for two or more risk factors according to body mass index (BMI) category and age

	Boys (n=907)*		Girls (n=907)*	
Variable	**OR (95% CI)†**	**P**	**OR (95% CI)†**	**P**
A) Odds for 2 or more borderline or unfavourable risk factors‡				
BMI category§				
No excess weight	1.0	–	1.0	–
Overweight	4.0 (2.6–6.1)	<0.0001	4.0 (2.8–3.9)	<0.0001
Obese	9.7 (5.8–16.2)	<0.0001	9.5 (5.2–17.3)	<0.0001
Age				
9 years	1.0	–	1.0	–
13 years	1.8 (1.1–2.9)	0.012	1.4 (0.97–2.1)	0.074
16 years	3.2 (2.1–4.7)	<0.0001	2.1 (1.4–3.1)	0.0001
B) Odds for 2 or more unfavourable risk factors‡				
BMI category				
No excess weight	1.0	–	1.0	–
Overweight	2.5 (1.1–5.8)	0.037	6.4 (3.3–12.2)	<0.0001
Obese	15.0 (7.9–28.8)	<0.0001	17.5 (8.3–36.8)	<0.0001
Age				
9 years	1.0	–	1.0	–
13 years	3.5 (1.2–10.2)	0.021	1.6 (0.8–3.2)	0.199
16 years	9.7 (3.6–26.0)	<0.0001	2.4 (1.2–4.6)	0.009

**Number of participants for whom data were available. The 'n' differs from the 'n' reported in Table 6 because of missing data on household income, smoking status and physical activity score; †Models were adjusted for household income, smoking status and physical activity score; ‡In A, the 7 risk factors included borderline or unfavourable apolipoprotein B, triglycerides, high-density lipoprotein cholesterol, insulin, glucose and systolic blood pressure, and unfavourable C-reactive protein, as defined in Table 1 and the 'Methods' section. In B, the 7 risk factors included unfavourable apolipoprotein B, triglycerides, high-density lipoprotein cholesterol, insulin, glucose, systolic blood pressure and C-reactive protein; §No excess weight – BMI <85th age- and sex-specific percentile values according to the Centers for Disease Control and Prevention 2000 growth charts, overweight – BMI ≥85th and <95th age- and sex-specific percentile values, obese – BMI ≥95th age- and sex-specific percentile values*

18% and 12% of obese boys and girls, respectively, had TG concentrations of 1.7 mmol/L or higher, which is similar to the prevalence of 13% and 18% of obese children and adolescents (both sexes) found in the Princeton City School District Study (26) and the Wilkes County Study (28), respectively. The lack of pediatric consensus on the definitions of cardiometabolic risk factors restricts comparisons between studies. For research and clinical purposes, it is desirable that the pediatric community reach consensus on threshold values to define cardiometabolic risk factors.

In 2003, the American Diabetes Association (43) changed the categorization for impaired fasting glucose (IFG) from 6.1 mmol/L or higher to 5.6 mmol/L or higher (38). Lowering the diagnostic threshold for IFG remains a controversial decision. Hence, we defined borderline and unfavourable fasting glucose as 5.6 mmol/L to lower than 6.1 mmol/L and 6.1 mmol/L to lower than 7.0 mmol/L, respectively. In the QCAHS, 2.1% of boys and 1.1% of girls had fasting glucose of 6.1 mmol/L to lower than 7.0 mmol/L, which is similar to the prevalence reported in NHANES III (1.8% prevalence overall) (44), the Princeton School District Study (2.0%) (45) and the Ankara Adolescent Obesity and Type 2 Diabetes Mellitus Study (2.2% in boys and 1.8% in girls) (46). We detected no difference in the prevalence of unfavourable glucose concentrations according to BMI category in either boys (P=0.14) or girls (P=0.99). In the QCAHS, lowering the diagnostic threshold to 5.6 mmol/L resulted in a marked increase in the prevalence of IFG in both sexes, with boys having a significantly higher prevalence than girls (18.2% versus 9.7%). Similarly, fasting glucose concentrations of 5.6 mmol/L or higher were more frequent in boys than girls in the 1999 to 2002 NHANES (14.8% of all boys and 7.3% of all girls) (47). In the QCAHS, the sex difference in the prevalence of fasting glucose concentrations 5.6 mmol/L or higher was not explained by a difference in the prevalence of overweight and obesity between sexes.

The estimated prevalence of all types of diabetes mellitus was 0.5% in the QCAHS, which is similar to the prevalence found in NHANES III (0.4% among adolescents 12 to 19 years of age) (44), the 1999 to 2002 NHANES (0.5% among adolescents 12 to 19 years of age) (47) and the Princeton School District Study (0.4%, mean age 14.3 years) (45). In contrast to adults, undiagnosed fasting glucose of 7.0 mmol/L or higher is an uncommon finding in youth; no case was found in the QCAHS (none of 2459) or in the Ankara Adolescent Obesity and Type 2 Diabetes Mellitus Study (none of 1647) (46), whereas only one case was found in the Princeton School District Study (one of 2501) (45) and two in the NHANES III (two of 2867) (44). However, considering the marked increase in the prevalence of overweight and obesity in youth (1,2), the tracking of BMI from childhood to adulthood (22) and the fact that excess weight is the most important risk factor for type 2 diabetes, many adolescents are at risk for the development of diabetes mellitus in early adulthood.

Limitations

One limitation of the present study is that the data were collected in a cross-sectional study design, so the duration of exposure to the risk factors could not be estimated. It is possible that if we had undertaken multiple measurements of these risk factors over time in the sample, the prevalence estimates might have been lower (41). Although categorization is a useful clinical tool, risk factors exert their adverse consequences on a continuum of biological levels rather than in a dichotomous manner (48). Youth classified as having borderline or unfavourable levels of a cardiometabolic characteristics would most likely remain in the undesirable one-half of the distribution after repeated measurements. In addition, the population we studied was mostly of white European descent, and our observations may not be applicable to other ethnic origins.

CONCLUSION

Because the risk factors investigated tracked from childhood to adulthood, and because they are clearly linked to adult disease, our findings raise concerns about the burden of adiposity on the current and future health of children, as well as on health care costs in Quebec and in Canada. Concerted efforts by clinicians, public health specialists and public policy makers are needed to prevent the adverse consequences of obesity on the health and well-being of future generations.

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